Fundamentals of HORTICULTURE

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Fundamentals of HORTICULTURE

A Textbook Designed for Courses in General Horticulture

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Dedicated

to the Memory of

Frederick Charles Bradford
(1887–1950)

Outstanding Teacher of Students in Horticulture

Preface

"Fundamentals of Horticulture" is the outgrowth of a mimeographed text which has been used for the course in General Horticulture at Clemson Agricultural College since 1936, at the Berry Schools since 1942, and as a basis for the lecture work at Mississippi State College since 1948. The purpose of the book is three-fold: to provide an opportunity for the student (1) to acquire a working knowledge of the fundamentals of plant growth, (2) to develop the ability to apply the fundamentals to the solution of practical problems, and (3) to obtain an appreciation of the significance of horticulture in human affairs. To meet these objectives, the book discusses the fundamentals, particularly the processes of photosynthesis, respiration, and water absorption and transpiration; and applies the fundamental processes to the growth and development of plants and to the solution of plant production problems. Thus, the book is primarily a "why" book. As Gardner, Bradford and Hooker,[1] Gardner,[2] Thompson,[3] and others have pointed out, the primary purpose of a college education is to train the student to think for himself and to stand on his own feet. To be sure, some practice in many plant-growing operations may be considered desirable, if not necessary. However, the emphasis

[1] Gardner, V. R., Bradford, F. C., and Hooker, H. D.: "Orcharding," New York, McGraw-Hill Book Company, Inc., 1927.

[2] Gardner, V. R.: "Basic Horticulture," New York, The Macmillan Company, 1942.

[3] Thompson, H. C.: "Vegetable Crops" 2d ed., New York, McGraw-Hill Book Company, Inc., 1931.

should be placed on an understanding of the fundamentals underlying a practice, rather than on acquiring proficiency in any given operation.

The text is divided into three parts: Part I, a study of the fundamental processes; Part II, the application of the fundamental processes to horticultural practices; and Part III, a discussion of the principal horticultural crops. Within each part, and for the book as a whole, the authors have endeavored to present a well-balanced view of the entire field rather than the field in which they have been trained or with which they are the most familiar, or have had the most experience. Thus, in Part I and Part II, as far as research data permit, fruit, vegetable and ornamental plants have been used to show the effect of the environment and of practices on the growth, development, and yields of horticultural crops. Further, three chapters in Part III have been given over to each of the three main groups: fruits, vegetables, and ornamentals. In other words, "Fundamentals of Horticulture" transcends departmentalization of knowledge within the field of horticulture. Thus, it should appeal to and be equally valuable for students who are interested primarily in the growing of fruits, or vegetables, or ornamentals, or in other phases of crop production.

The use of the book should eliminate the necessity of taking extensive notes in class—always a time-consuming practice—and, as a result, provide for more time for discussion and explanation of important points and, if desirable, for a more extended coverage of the field of horticulture. In addition, a study of the assignments just prior to their discussion in class will place on the student the responsibility for fundamentals, and afford greater opportunity to the instructor to make local, regional, national, or world-wide application.

The authors have departed from the usual or traditional pattern in the development of the subject matter of a course in General Horticulture. They believe that students will more fully appreciate the significance of horticulture in human affairs *after*, rather than *before*, they have received instruction in specific fields. Inasmuch as a person with a knowledge and appreciation of music can more fully enjoy and appreciate a classical composition, so the student is in a better position to appreciate horticulture as his knowledge of horticulture increases rather than at the beginning of the course when his knowledge of and familiarity with the subject are relatively nil.

Although many factors operate simultaneously on any given process, the text has been developed on the assumption that effective teaching consists, partially at least, of the presentation of the effect of one factor

at a time. In general, students at the freshman and sophomore levels can hardly be expected fully to grasp and understand at first the effect of two or more factors and their interaction on any given process operating at the same time. As their knowledge of the subject matter increases, the relative influence of two or more factors on the same process can be more fully understood and appreciated.

The authors believe that the text is applicable to courses in General Horticulture given on either the semester or the quarter basis. To achieve the objectives of the book, not all of the chapters need be assigned. This is particularly true of certain chapters in Part II, and all of the chapters in Part III. For example, since time may not permit a discussion of all of the chapters in Part III, representative chapters may be selected from each of the three main groups of crops: fruits, vegetables, and ornamentals. For example, students in the Northeast or Midwest regions may be more interested in the apple or potato, while those in the Southeast region may be more interested in the citrus fruits, pecan, or sweetpotato.

Finally, the authors realize that the book is far from perfect—the great difference between what the text is and what they would like it to be. To improve the book and to increase its usefulness, they would appreciate the interest of all who read or use the book. They would particularly welcome suggestions for improvement from their fellow teachers of courses in General Horticulture.

In conclusion, the authors express appreciation to all colleagues and co-workers who have assisted in any way in the preparation of this text. In particular, they are indebted to Professor E. W. McElwee and Professor F. S. Batson, both of Mississippi State College, for data and suggestions for the development of Chapters 22, 23, and 24; to Dr. Jackson B. Hester, of Campbell Soup Company, for use of the cuts for Figures 54, 59, and 67; to the several co-workers who provided photographs; and to Professor Alex Laurie of The Ohio State University, Professor W. S. Anderson of Mississippi State College, and Professor H. J. Sefick of Clemson Agricultural College for their encouragement. The authors also extend thanks to Miss Clyde Reba Crawford and to the Misses Betty Jane and Ruth Catherine Murray for assistance in typing the manuscript, and to Mrs. Margery Batson for assistance in reading proof.

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Part I

Plant Growth and Development

(A Brief Review)

1

Fundamental Plant Processes, Tissues, and Structures

Assignment 1

FUNDAMENTAL PLANT PROCESSES

The fundamental processes in higher plants are: (1) Photosynthesis, (2) respiration, and (3) water absorption and transpiration. The student should have a working knowledge of these processes in order to acquire the ability to understand plant growth and development.

PHOTOSYNTHESIS

Nature of Photosynthesis. Photosynthesis is essentially a biochemical reaction. Carbon dioxide and water combine through the agency of chlorophyll and in the presence of light to form carbohydrates and to liberate oxygen. *The function of this reaction is to transform the kinetic energy of light to the potential chemical energy of foods.* In this way, the energy that comes from the sun is fixed in usable form in the green tissues of plants. This fundamental reaction is illustrated as follows: (1) The specific formula shows the number of molecules of carbon dioxide and water and the amount of light energy, measured in calories, necessary to make one molecule of glucose. (2) The general formula illustrates that the making of all foods is part of the photosynthetic reaction.

Specific:

$$6CO_2 + 6H_2O + 677.2 \text{ cals. of light energy} \xrightarrow{\text{(chlorophyll and enzymes)}} C_6H_{12}O_6 + 6O_2$$

General:

$$\text{carbon dioxide} + \text{water} + \text{light} \xrightarrow{\text{(chlorophyll and enzymes)}} \text{foods} \begin{cases} \text{carbohydrates} \\ \text{proteins} \\ \text{fats} \end{cases} + \text{oxygen}$$

Essentially, photosynthesis is a manufacturing process. Carbon dioxide and water are the raw materials. The carbohydrates and related substances, the fats and related substances, and the proteins are the manufactured products. Oxygen may be considered the by-product. The chloroplasts, small blobs of protoplasm inside the manufacturing cells, are the factories. Chlorophyll may be considered the machinery and enzymes the lubricators of the machinery. The raw materials, carbon dioxide and water, must be brought into the factories, the chloroplasts, before the reaction can take place. To reach the chloroplasts, carbon dioxide in the air passes through small openings, stomata, in green tissues, and water in the soil passes through the finer portions of the root, usually the root hairs, and through the conducting vessels of the root and stem—the xylem.

The combination of carbon dioxide and water is effected by the green pigment—chlorophyll. It exists on the surface of the chloroplasts. During photosynthesis chlorophyll absorbs the radiant energy of the sun. Some of the absorbed energy is used in the union of carbon dioxide and water. Thus, the ability of chlorophyll to absorb radiant energy makes life on this planet possible, and *the function of chlorophyll is to absorb light in photosynthesis.*

Chlorophyll is rather complex in chemical composition. It consists of two pigments, chlorophyll-α and chlorophyll-β. In both pigments magnesium is the center of the molecule, and chains of carbon compounds are on the outside. Since chlorophyll is continually being destroyed, conditions favorable for its continual formation are necessary. These are a carbohydrate supply, light, temperature, oxygen, enzymes, and certain nutrients in the soil solution. In general, chlorophyll formation takes place in moderately wide temperature, usually 35° to 100° F., in moderate light intensity, and in the presence of nitrate and ammonium-nitrogen and certain substances supplying magnesium, manganese, and iron. *Nitrogen and magnesium are part of the chlorophyll molecule and manganese and iron serve as catalysts in chlorophyll formation.*

THE MANUFACTURED COMPOUNDS

The manufactured compounds are: (1) The carbohydrates and related substances, (2) the fats and related substances, and (3) the proteins. From

the standpoint of plant growth and development, the carbohydrates are particularly important.

The Carbohydrates and Related Substances. The carbohydrates contain the elements carbon, hydrogen, and oxygen and are the principal constituents of all plant tissues; for example, the dry matter of a 56-pound bushel of sweetpotatoes weighs from 19 to 20 pounds. Of these 19 to 20 pounds, 17 to 18 pounds consist of carbohydrates.

From the standpoint of their function in plants the carbohydrates are classified as follows: (1) Those which are soluble in water and (2) those which are insoluble.

THE PRINCIPAL WATER-SOLUBLE CARBOHYDRATES. These are: (1) Glucose, (2) fructose, and (3) sucrose. Of these sugars *glucose* is very important. This substance is considered the first sugar formed in photosynthesis, the most commonly transported sugar and the main sugar used in respiration. Thus, glucose occurs in all living cells and it is the mother substance from which all other foods are derived. *Fructose* and *sucrose* are very sweet sugars, and as such, help to augment the quality of many economic plants. Sucrose occurs in mature fruits and certain roots (sweetpotato, sugar beet) and bulbs (onions). In the plant it is a storage form of carbohydrate.

THE INSOLUBLE CARBOHYDRATES. The insoluble carbohydrates are of two kinds: (1) Those which are stored in the plant's tissue, the reserve carbohydrates, and (2) that which is part of the plant's tissue, the structural carbohydrate.

THE PRINCIPAL RESERVE CARBOHYDRATES. These are: (1) Starch, (2) inulin, and (3) hemicellulose. *Starch* is derived from glucose. It is the most important energy reserve or storage carbohydrate of plants. In other words, starch is to plants what fats are to animals. It is stored in the form of grains, which vary in size, shape, and number. In general, storage tissues contain larger grains than nonstorage tissues. *Inulin* is derived from fructose. In some plants, the fleshy roots of dahlia and the tubers of Jerusalem artichoke, carbohydrates are stored in this form instead of starch. *Hemicelluloses* are derived from mixtures of glucose and other sugars. In general, they serve as reserve materials and are found in the endosperm of the grass, lily, and palm families.

THE STRUCTURAL CARBOHYDRATE. *Cellulose* is the chief structural carbohydrate. It is the main building material of all cell walls of plants. When cell walls become woody the cellulose combines with lignin to form lignocellulose, the strengthening material of woody plants.

Manufactured foods related to the carbohydrates are: (1) The pectic substances, (2) gums and mucilages, (3) organic acids, and (4) pigments.

The *pectic substances* are the materials which cement together the cellulose fibers of the cell walls. When the pectic substances are hydrolized by enzymes in the plant, they become soluble in water. As a result, the tissues soften and finally fall apart. This softening occurs when fruits of the apple, pear, peach, and other products become over-ripe.

Gums and mucilages are substances which possess the ability to attract water to their surfaces. This water is bound and can no longer enter into the metabolic activities of the plant. Because these substances bind water they are hydrophylic, meaning water-loving.

The principal organic acids are oxidation products of soluble carbohydrates. *Acetic acid* is the principal constituent of vinegar and is made by fermentation of the juice of apples and other fruits. *Lactic acid* is a constituent of sauerkraut and is formed during the fermentation of cabbage. *Malic, tartaric,* and *citric acids* occur in the fruits of many crops such as apples, pears, tomatoes, and citrus fruits. Ascorbic acid or vitamin C occurs in many products. Excellent sources are the citrus fruits, peppers, pineapples, and tomatoes.

Pigments are chemical compounds which give the sensation of color. In plants there are two kinds: (1) Plastid and (2) sap. *Plastid pigments* occur in the surface of plastids—small blobs of protoplasm within certain cells. The principal plastid pigments are: (1) Chlorophyll, (2) carotene, and (3) xanthophyll. *Chlorophyll* is the green pigment of plants and absorbs light in photosynthesis. *Carotene* and *xanthophyll* are yellow pigments. Because carotene is the precursor or mother substance of vitamin A, it is essential for the nutrition of plants and animals. Carotene is associated with chlorophyll and thus occurs in all green tissues. In addition it is stored in the fleshy roots of carrot, in the yellow-fleshed varieties of sweetpotatoes, turnips, and rutabagas, and in tomato fruits and yellow-fleshed varieties of peaches.

The principal sap pigments are: (1) The anthocyanins and (2) the flavones. The *anthocyanins* are responsible for the reds, blues, and purples of many flowers, fruits, and vegetables, and the *flavones* are responsible for the yellows and ivorys.

The Fats and Related Substances: FATS. Fats contain the same elements as the carbohydrates—carbon, hydrogen, and oxygen—only in different proportion. From the standpoint of the plant, fats are excellent reserve energy materials. They are insoluble in water. Since they are liquids fats

occupy storage space efficiently. They have a low oxygen content and a high energy value per unit weight. Fats, in common with other storage forms, assist in nourishing the seedling plant until it can manufacture its own foods. The formation of fats from carbohydrates is illustrated as follows:

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$$\text{carbohydrates} \xrightarrow{} \left\langle \begin{array}{c} \text{(lipase)} \\ \text{fatty acids} \\ + \\ \text{alcohols} \end{array} \right\rangle \xrightarrow{} \text{fats}$$

Related Substances. Substances related to the fats are: (1) The waxes, (2) sterols, (3) lipins, and (4) essential oils. *Waxes* occur on the epidermis of plants and reduce transpiration. *Sterols* are complex secondary alcohols. An important sterol is ergosterol. When ergosterol is irradiated with ultraviolet light, it is changed into several substances including calciferol or vitamin D_2. *Lipins* are fatty-like substances containing nitrogen and phosphorus. An important lipin is lecithin. Lecithin is found in all living cells, particularly in the living membrane. *Essential oils* are responsible for the distinctive odors and flavors of plants. They are not oils in the strict sense but, since they are soluble in chloroform, ether, and similar compounds, they are discussed with the fats. Important essential oils are oils of lemon, wintergreen, cloves, and peppermint, and menthol, camphor, and thymol.

The Proteins. Proteins are colloids of high molecular weight and of complex chemical composition. They contain the elements carbon, hydrogen, oxygen, and nitrogen. In addition, some proteins contain phosphorus and others contain sulfur. Proteins are made by combining sugars with certain compounds containing nitrogen. Amino acids are the first substances formed. These then condense to form the complex proteins. Steps in the process are: (1) The reduction of nitrate-nitrogen to ammonium-nitrogen, (2) the reaction of sugars with the ammonium compound to form amino acids, and (3) the condensation of the amino acids to form the proteins. The reaction is illustrated as follows:

$$\underset{\text{nitrate-nitrogen}}{NO_3\text{—}N} \xrightarrow{\text{(reductase)}} NH_4\text{—}N + \text{sugar} \xrightarrow{\text{(enzymes)}} \text{amino acids} \xrightarrow[\text{(condensation)}]{} \text{proteins}$$

Protoplasm, the living substance of plants, consists mostly of proteins.

Respiration

Nature of Respiration. Respiration, like photosynthesis, is essentially a biochemical reaction. Manufactured food is decomposed to carbon dioxide

and water with the liberation of heat and other forms of energy. *The function of this reaction is to transform the potential chemical energy of foods to various forms of kinetic energy.* By this reaction the light energy reserve, built up by plants in the form of foods, becomes available for all plants and animals. All higher plants and all animals secure energy for their vital needs through this process. In other words, *respiration in plants and in animals has exactly the same function—the liberation of energy.* The specific and general equations follow: the specific form showing the oxidation of one molecule of glucose, the general form illustrating the oxidation of all food substances. Glucose is the usual food used in respiration.

Specific:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2 \xrightarrow{\text{(enzymes)}} 6CO_2 + 6H_2O + 677.2 \text{ cals. of heat energy}$$

General:

$$\underset{\text{(usually glucose)}}{\text{foods} + \text{oxygen}} \xrightarrow{\text{(enzymes)}} CO_2 + H_2O + \text{heat and other forms of energy}$$

Photosynthesis and Respiration Contrasted. The student will note that respiration is exactly the reverse of photosynthesis. A contrast between these processes will help to clarify the differences between them.

Photosynthesis	*Respiration*
Takes place in green cells only	Takes place in all living cells
Takes place in light only	Takes place in light and in darkness
Absorbs light and fixes energy (endothermic)	Liberates heat and other forms of energy (exothermic)
Always increases dry weight of green plants	Always decreases dry weight of green plants

These processes, photosynthesis and respiration, are undoubtedly the most important chemical reactions known to man. Without them all living things could not exist. Without them diamonds, coal beds, vast oil deposits, soil, and great forests would never have been formed. Without them the great industries of pulp and paper, nitrocellulose, rayon, lacquers, dyes, and the great plant and animal industries would be unknown. In short, photosynthesis and respiration are the foundation of agriculture.

Water Absorption and Transpiration

Water absorption and transpiration are essentially biophysical processes. Water is absorbed in the liquid state, principally in the region of the root

hair zone, and water is lost in the vapor state from the tissues of plants. *This loss or outgo of water in the vapor form is called transpiration.* Although any part of a plant exposed to the air may give off water vapor, the leaves, because of their structure and position, give off the most.

A prime function of water within the plant is to maintain turgor within the living cells. Living cells are in a state of turgor when they are fully stretched. To maintain turgor the amount of water absorbed must, in general, equal the amount of water transpired. When the rate of absorption is much less than the rate of transpiration, the living cells lose their turgor, the guard cells decrease in size, the stomata close, and photosynthesis slows down or entirely stops—as a result yields are low. Thus, when plants are growing in soil with insufficient water, as most of them are for occasional periods in regions of poorly distributed rainfall and lack of supplemental irrigation, water absorption and transpiration assume great practical significance.

DIFFUSION AND OSMOSIS

Diffusion and osmosis are processes necessary for the proper functioning of photosynthesis, respiration, and water absorption and transpiration. Both processes are essentially biophysical in character.

Diffusion. Suppose a vessel is filled with water and crystals of sodium nitrate or cane sugar are dropped into it. The ions of sodium nitrate, or the molecules of sugar, soon become equally distributed or concentrated in all parts of the water. In other words, *the particles of sodium nitrate or sugar have moved from regions of relatively high concentration to regions of relatively low concentration.* In much the same way, mineral substances get into the plant from the soil solution. Consider, for example, the absorption of nitrate or ammonium ions. In the root hairs and leaves, sugars and nitrate or ammonia-nitrogen combine to form proteins. Hence, at the place of protein formation, these nitrogenous materials are constantly taken out of solution to form proteins and the concentration of the nitrate or ammonium ions is reduced. Thus, the relatively greater concentration of nitrate ions or ammonium ions existing in the soil solution enables them to pass from the soil solution into the plant.

Scientists have found that minerals are absorbed independently of each other, and independently of the movement of water. In fact, a mineral can move out of the root hair while water moves in. Factors which influence the rate of absorption of any mineral are: (1) Its relative concentration in the plant sap and in the soil solution, (2) its density, and (3) the

temperature of the system. With other factors favorable, the higher the concentration of any mineral in the soil compared to its concentration in the plant sap and the higher the temperature of the soil solution, the faster will be the movement of the mineral from the soil into the plant.

Osmosis. Suppose a vessel A contains water only, and a vessel B contains both sugar and water. Suppose a glass tube is joined to the bottom of both vessels, and that this tube contains a membrane which allows only the molecules of water to pass through it. Because of the greater concentration of water in vessel A than in vessel B, the water molecules will pass from A to B at a faster rate than from B to A until the rate of diffusion is the same in both directions. This movement of water from regions of higher concentration of water to regions of lower concentration, or from regions of lower concentration of solution to regions of higher concentration of solution, is called osmosis.

Water enters the plant by means of osmosis. The plasma membranes of the root hairs behave as semipermeable membranes. They will allow water molecules to diffuse through them more readily than sugar molecules. Since the concentration of water is less within the cell than in the soil, by virtue of the kinetic energy of its molecules water passes from the soil to the cell and from cell to cell until it reaches the conducting tubes—the xylem. Thus, *osmosis is simply the passage of water through a membrane* and the means by which water gets into the plant.

Questions

1. Set up the equations, general and specific, for photosynthesis and for respiration.
2. What is the purpose of photosynthesis?
3. Photosynthesis may be considered a manufacturing process. Explain.
4. What is the function of chlorophyll?
5. A plant with a large quantity of chlorophyll (large leaf area) can make more foods in a given time than a plant with a small quantity of chlorophyll (small leaf area). Explain.
6. Investigations have shown that apple trees with dark green leaves make from 2 to 4 times more sugars per unit time than trees with light green leaves. Explain.
7. Disease infection and insect infestation reduce photosynthesis, growth, and yield. Explain.
8. A lack of iron (Fe), magnesium (Mg), and manganese (Mn) in the soil solution markedly decreases growth and yield. Explain.
9. Chemical analyses have shown that snap beans grown on soil lacking

in soluble iron contain less sugars than those growing in soil containing soluble iron. Explain.

10. What is: the main carbohydrate used in respiration? the main storage carbohydrate? the main structural carbohydrate?
11. Name two horticulture products that are particularly high in: (1) Starch, (2) carotene, (3) reserve proteins, and (4) fats.
12. Contrast the processes of photosynthesis and respiration from the point of view of: (1) Weight and energy relations, (2) seat of operation, and (3) time of operation.
13. The dry weight of all green plants decreases at night. The dry weight of deciduous perennials decreases during the winter. Explain.
14. Photosynthesis and respiration are considered the most important chemical reactions known to man. Explain.
15. During hot-dry weather plants transpire more water than during cool-dry weather or cool-wet weather. Explain.
16. What is the difference between respiration and transpiration?
17. Illustrate the Law of Diffusion by showing how carbon dioxide is absorbed.
18. Explain how water is absorbed by plants.
19. Photosynthesis is necessary for the absorption of water. Explain.

THE PRINCIPAL PLANT TISSUES

Plants are composed of cells. These cells may be regarded as the structural units of a plant in much the same way as bricks are considered the structural units of a building. Cells vary in size, shape, and arrangement. Some cells are small, some large, some box-like, and others are long and fiber-like. In some tissues they appear like the stones in a stone wall with air spaces between them; in other parts they appear like bricks in a building with no air spaces between them.

Cells do not work alone; they work together in groups. For example, the group of box-like cells at the growing points of the roots and stems has the common function of cell division, and the group of cells which constitute the phloem has the common function of food transportation. *Groups of cells which have a common function are called tissues.* There are two types: (1) Simple and (2) complex. In simple tissues the individual cells are similar in size, shape, and arrangement. Conversely, in complex tissues the individual cells are dissimilar in size, shape, and arrangement. Principal simple tissues are: (1) Meristem, (2) parenchyma, (3) collenchyma, (4) sclerenchyma, and (5) cork. Principal complex tissues are: (1) Phloem and (2) xylem.

Simple Tissues

Meristem. Meristem is living tissue. It presents the most active manifestation of life in plants. Individual cells are small and box-like. They possess thin pliable walls, dense cytoplasm, and a large centrally located nucleus. The function of meristem is to make new cells. In this way the plant increases in size. *Meristem does not make foods; it uses them.* These foods are used to make the various constituents of the cells—the walls and the protoplasm—and to provide energy. When plant cells are dividing, they are working and must have a source of energy. Thus, the fundamental process, as far as meristem is concerned, is respiration.

Meristem is of two types: (1) Primary and (2) secondary. The *primary meristem* gives rise to the primary plant body and provides for growth in length. The *secondary meristem* gives rise to the secondary plant body and provides for growth in thickness or circumference. The *vascular cambium* gives rise to the secondary phloem, the secondary xylem, and the medullary rays, and the *cork cambium* gives rise to the layer of outer cork. As discussed later, these tissues, vascular cambium and cork cambium, are very important in certain horticultural practices such as in budding and grafting, and in certain plant activities as in the healing of cut and bruised surfaces, and in the production of roots from shoots. Note the group of meristematic cells in the root tip of onion in Figure 1.

Parenchyma. Parenchyma is living tissue also. Although individual cells of parenchyma differ in size, shape, and arrangement, according to the work they perform, in general they are larger and more elongated and possess thicker walls, less dense cytoplasm, and smaller nuclei than the meristem. Unlike the meristem, some types of parenchyma contain plastids, small blobs of dense protoplasm, and comparatively large vacuoles between the cytoplasmic strands. The kind and function of parenchyma vary greatly. Principal kinds are: (1) Food-making cells, (2) epidermis, (3) cortex, (4) endodermis, (5) pericycle, (6) sieve tubes, (7) pith, and (8) nectaries.

Food-making Cells. Food-making cells are relatively thin walled and possess chloroplasts, the food-making factories of the plant. In leaves they are of two types: (1) Palisade and (2) spongy. The *palisade tissue* is located in the upper part of the leaves. Individual cells are elongated with the long axis at right angles to the epidermis. In general, there are one, two, or more layers, depending largely on the degree of light intensity. Plants growing in high light intensity usually have two or three layers of

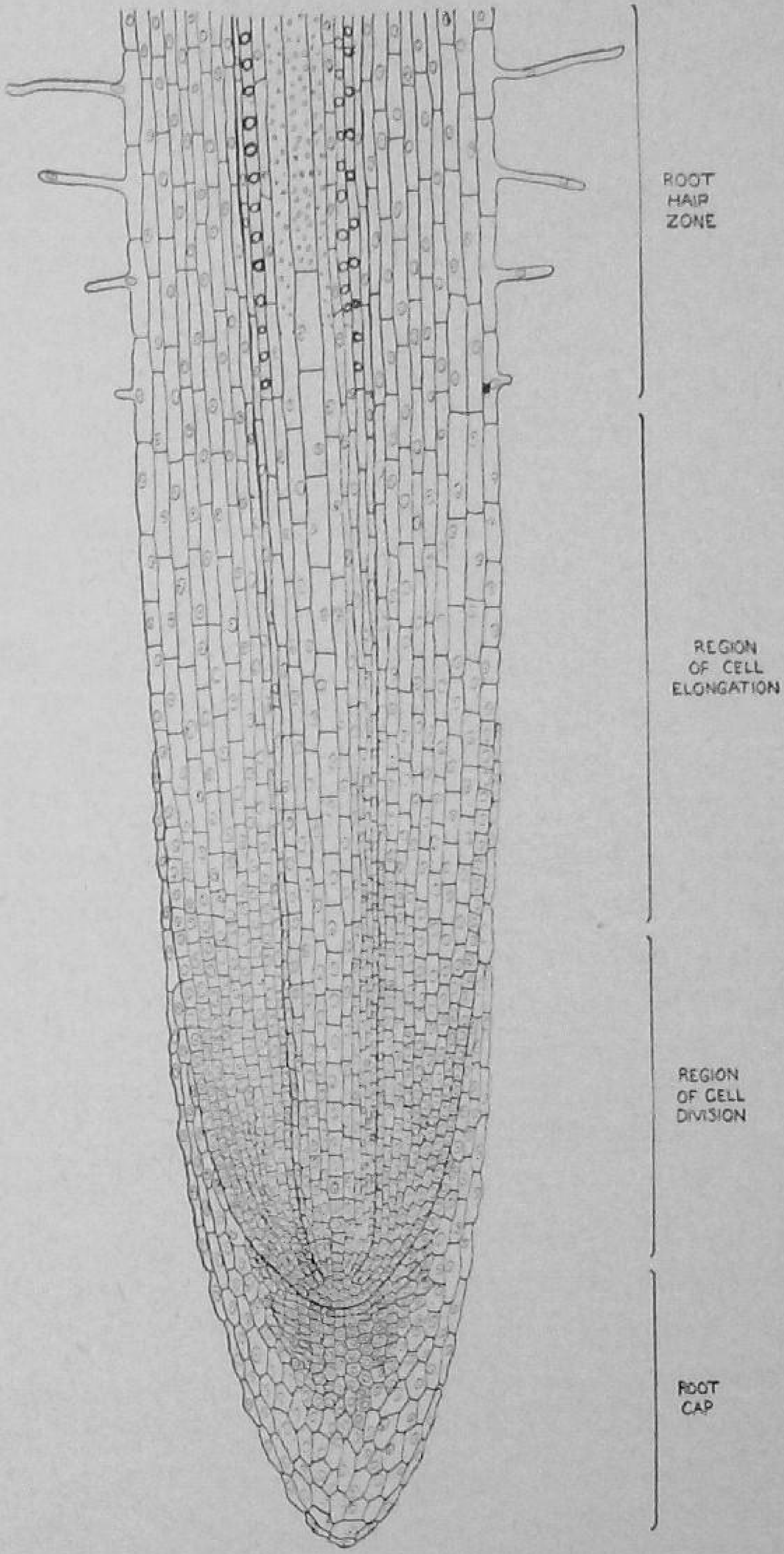

FIG. 1. Longitudinal section of root tip. (Courtesy, J. F. Locke, Mississippi State College.)

palisade cells, and those growing in low light intensity usually have one layer. The *spongy tissue* is located in the lower part of the leaves. Individual cells are roundish and have intercellular spaces between them. These intercellular spaces facilitate the diffusion of carbon dioxide to the food-making chloroplasts. Thus, the prime function of the green cells is the manufacture of food (see Figure 11).

EPIDERMIS. The epidermis is the surface layer of leaves, of herbaceous stems, and of fruits and roots not covered with cork. In most plants it is one cell thick and varies in structure according to its particular function. In leaves and green stems this tissue consists of colorless cells and green cells called the guard cells. The *guard cells* contain chloroplasts. These chloroplasts possess the ability to make sugars just like the chloroplasts in the palisade and spongy tissue. In the region of the root hair zone the epidermal cells are of one type. They are all colorless, possess thin walls, and absorb water and nutrients. Many of these cells become tubular and are called root hairs (see Figure 5).

CORTEX. The cortex is situated just below the epidermis and consists of round or elongated, thin or moderately thick-walled cells. The thickness of the walls depends on the function which they perform. In the region of the root hair zone, the cortex serves as an osmotic system for the absorption of water and the passage of nutrients. In the green stem the cortex contains chloroplasts and thus manufactures food. In other portions of the plant the cortex has thick walls and stores food.

ENDODERMIS. The endodermis is a single layer of cells between the cortex and pericycle. Although the exact function of the endodermis in stems is unknown, its function in roots is essential for the growth and well being of the root system. *This function is to prevent the diffusion of sugars from the phloem to the soil in the region of the root hair zone.* As stated previously, sugars are necessary for the making of new cells at the growing points. These sugars are made in the tops and are translocated downward in the phloem of the stem and root to the growing points. In the root hair zone the transverse and tangential walls of the endodermis are suberized. The suberization of these walls prevents the diffusion of substances through the walls and the protoplasm controls the amount of sugars that pass out into the cortex. Thus, the sugars, instead of leaking out in undue quantities through the region of the root hair zone, pass down to the growing point where they are used for the making of new cells.

PERICYCLE. The pericycle consists of one to several layers of cells between the endodermis and conducting vessels. In stems certain groups

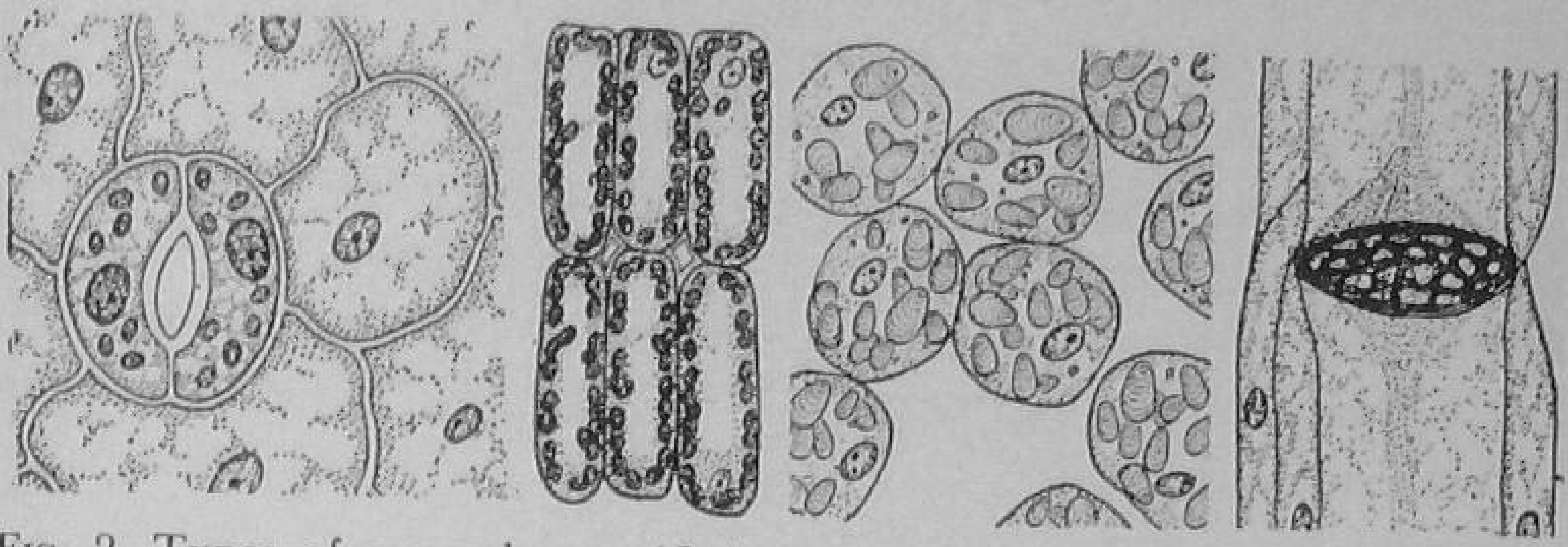

FIG. 2. Types of parenchyma. (*Left to right*) Guard, palisade, storage, and food-conducting cells.

have thick-walled fiber-like cells which help the plant to withstand stresses and strains. In roots the pericycle gives rise to lateral roots.

SIEVE TUBES. The sieve tubes are an essential part of the vascular bundles and consist of vertical rows of elongated cells. The side walls are thin, but the end walls are thick and minutely perforated. Strands of cytoplasm extend through these perforations from cell to cell. Thus, the living substance of the cells of the tubes is connected. *The prime function of the sieve tubes, together with the companion cells, is to transport manufactured food* from the chlorophyll-containing tissues where they are made to the tissues where they are stored or used.

PITH. The pith is found in the central portion of stems and in some roots. This tissue is made up of relatively large thin-walled cells frequently with numerous intercellular spaces. The function of the pith is to store food, particularly starch—the most important reserve carbohydrate.

NECTARIES. The nectaries or nectar glands secrete various substances, particularly sugar and essential oils, for the attraction of insects. They are situated in the base of the flowers and in the leaves and stems of plants. The form and size of the glands of horticultural plants vary greatly. For example, in lilac the glands consist of a single epidermal cell; in geranium they consist of hairs on the surface of the leaves; in buttercup they form a shallow cavity at the base of the flowers; and in nasturtium they form a deep pouch at the base of the flowers. Figure 2 shows various types of parenchyma cells. Note the differences in size, thickness of walls, and arrangement.

Collenchyma. Collenchyma is living tissue also. The individual cells usually are elongated and have the same general appearance as those of the parenchyma. Their distinguishing characteristic is the thickened corners of the walls. These thickened walls help the plant to withstand stresses and strains. Collenchyma is usually found in the cortex just beneath

the epidermis of young herbaceous stems and petioles, the midrib of leaves, and in pedicels and peduncles of flowers.

Sclerenchyma. Sclerenchyma is dead tissue. The walls of the cells become hard and lignified. There are three types: (1) Stone cells, (2) fiber-like cells, and (3) xylem vessels. *Stone cells* are irregular in shape and thick-walled with exceedingly small cell cavities; and they occur mostly in fruits and seeds. Examples are: the grit cells in the fruit of certain varieties of pear, and the shells of certain nut fruits—pecan, walnut,

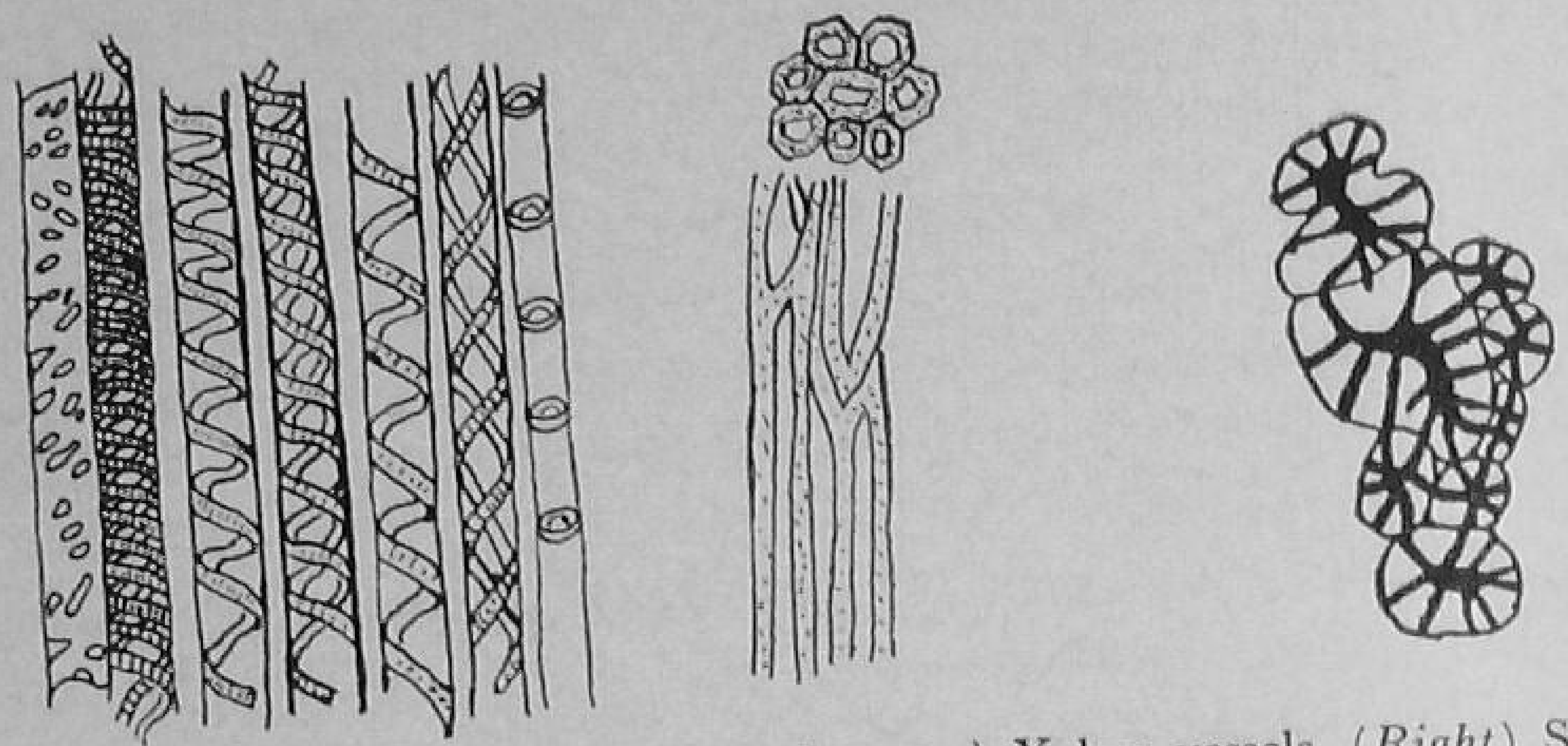

FIG. 3. Types of sclerenchyma. (*Left and center*) Xylem vessels. (*Right*) Stone cells.

almond, and coconut. *Fiber-like cells* are extremely long, thick-walled, and tapering. The tapered ends dovetail with each other so that the plant can withstand stresses and strains, as, for example, the forces of the wind. These fibers may occur, as necessity requires, in the cortex, pericycle, phloem, or xylem of stems and roots. *Xylem vessels* are long, thin-walled and pipe-like, and the walls are strengthened according to various patterns and designs. Figure 3 shows the three types of sclerenchyma.

Cork. Woody plants, the old stems of herbaceous plants, and certain storage structures are covered with a tissue called cork or bark. This tissue takes the place of the epidermis and is formed by the division of the cork cambium. Individual cells are rectangular with no intercellular spaces. The walls are relatively thin and are impregnated with a fatty-like substance called suberin and with tannin and other substances. The suberin makes the tissue impermeable to water and gases, and the tannin renders the tissue resistant to the attacks of rot-producing organisms. Thus, the function of the cork layer is to protect the stem or root from excessive loss of water and against the attack of rot-producing organisms. Figure 4 shows the replacement of the epidermis by a layer of cork.

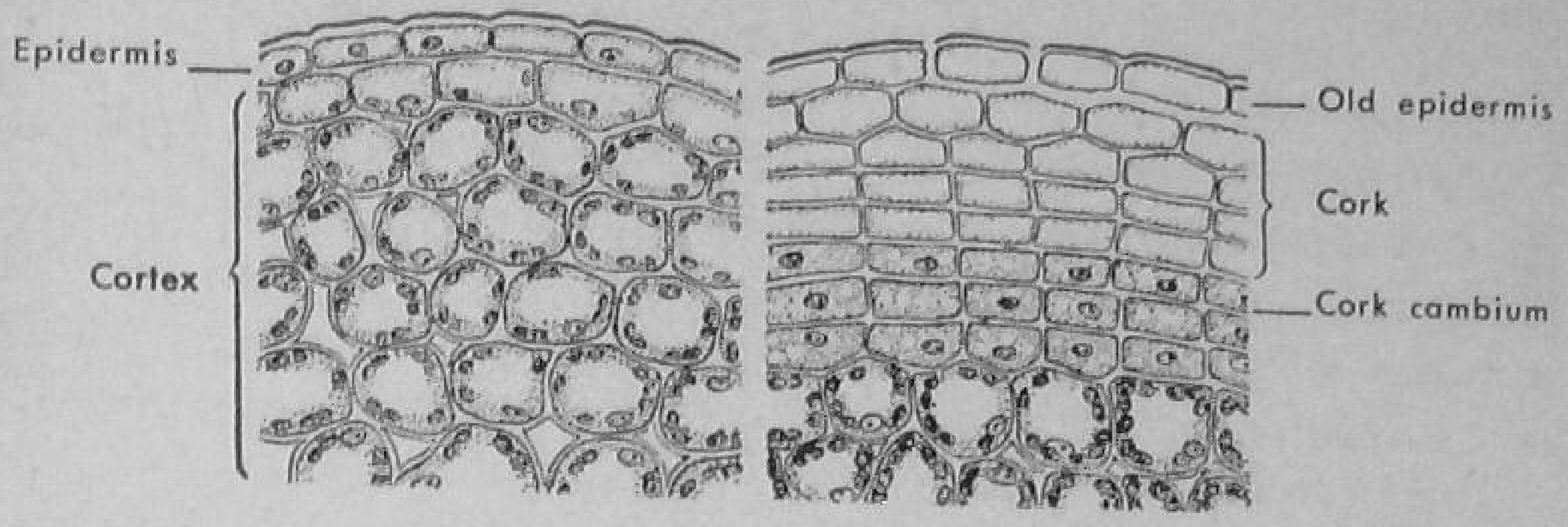

Fig. 4. Cross-section of primary stem and secondary stem showing replacement of epidermis by layer of cork cells.

Complex Tissues

In addition to simple tissues which have one kind of cell only, food-making plants contain complex tissues which contain more than one kind of cell. The principal complex tissues are: (1) The phloem and (2) xylem.

Phloem. The phloem consists of sieve tubes, companion cells, and fibers. The sieve tubes and companion cells conduct the manufactured food and the fibers give support. Thus, *the primary function of the phloem is to conduct the manufactured food.*

Xylem. The xylem consists of long tubes through which water and nutrients pass. Thus, *the primary function of the xylem is to conduct water and nutrients.* The phloem and xylem are collectively called *vascular bundles.*

The student should remember that all tissues work together for the growth and development of the entire plant. In other words, the various tissue systems are interdependent. For example, the food-manufacturing cells depend on the root hairs and conducting tissues for their water supply. The water-absorbing cells depend on the soluble sugars manufactured by and transported from the food-manufacturing cells for their osmotic pressure. Without these sugars these water-absorbing cells would not be able to absorb water. Can you think of any other examples of interdependence?

Questions

1. Do cells work alone? How do they work? Explain fully, giving an example.
2. What is: a simple tissue? a complex tissue?
3. Name the principal tissues in plants.

4. Draw a meristematic cell. Label all parts.
5. Why are the walls of meristematic cells thin and pliable?
6. What is the function of the meristem?
7. What is the fundamental process concerned with meristem?
8. Name the two types of meristem. Where is each type found?
9. How do parenchyma cells differ from meristematic cells?
10. Name four types of parenchyma cells and state the function of each.
11. Draw from memory: an epidermal cell, a carbohydrate-manufacturing cell, a root hair. Label all parts. Show how the size, shape, and structure of each cell is adapted to its particular function.
12. How does collenchyma differ from parenchyma tissue? What is the prime function of collenchyma?
13. Draw: a pipe-like cell, a fiber-like cell. Show how each is adapted to its particular function.
14. What is the function of: the xylem? the phloem?

Assignment 2

PRINCIPAL PLANT STRUCTURES AND THEIR FUNCTIONS

Since tissues perform special functions, so do groups of tissues, which are called structures, perform certain specific functions. The principal structures of higher plants are: (1) The root system, (2) the stem system, (3) the leaves, (4) the flowers, and (5) the fruit and the seed.

The Root System

The root system of higher plants may be divided into two more or less distinct parts: (1) That part which grows in length and (2) that part which grows in diameter. These parts in turn may be divided into various regions, according to the particular function which each region performs.

GROWTH IN LENGTH

The part of the root system which grows in length is divided into four regions: (1) Cell division, (2) cell elongation, (3) water and nutrient absorption and initial differentiation, and (4) lateral root formation and further differentiation.

The Region of Cell Division. This consists of a growing point and a root cap. The growing point is a group of meristematic cells. When the root is growing these cells are dividing. In fact, the rate of root extension depends largely on the rate of division of these cells. The root cap is a thimble-shaped mass of cells which covers the growing point. Its function is to surround and protect the soft meristematic cells of the growing point. Obviously, *the primary function of the region of cell division is the making of new cells.*

The Region of Cell Elongation. This region is located just back of the growing point. It consists of meristematic cells which have elongated; that is, the longitudinal axis has increased more than the transverse axis. These cells absorb large quantities of water. This abundant absorption increases the turgor pressure within the cells and the walls become permanently stretched. Thus, *the region of cell elongation is responsible for a certain amount of growth in length.*

The student should remember that large quantities of sugars and proteins are necessary for a rapid rate of cell division and that abundant water is necessary for cell elongation. Thus, disease infection, insect infestation, mechanical injury, or pruning of the top system will naturally limit the extension of the root system.

The Region of Water and Nutrient Absorption and of the Initial Stages of Differentiation. Located just back of the region of elongation, this region is often referred to as the root hair zone. The cells of this region have differentiated into distinct tissues: (1) Epidermis, (2) cortex, (3) endodermis, (4) pericycle, and (5) vascular bundles. The *epidermis* consists of a single layer of cells. The prime function of this tissue in this region is the absorption of water and nutrients. To absorb water most effectively many cells elongate and are called root hairs. Individual root hairs are slender and tubular. Their walls are very thin and are made of cellulose and pectin or of pectinaceous material only. They are also short-lived (a few hours to a few weeks). When the meristematic cells of the growing points are dividing, root hairs are forming continuously just behind the region of elongation. In this way new stores of water and nutrients become available to the plant.

When plants are transplanted, the root hairs are easily broken off and are easily dried out. This is one reason why many plants are handled very carefully when they are transplanted, especially if they have a large leaf surface or if the evaporating power of the air is high. The successful greenhouse gardener and nurseryman has learned from experience to handle

plants carefully in root-handling operations and particularly in transplanting, a practice discussed in Chapter 12.

For a given species, the osmotic pressure of the root hairs varies with the osmotic pressure of the soil solution. Thus, sudden and drastic changes in the water supply and concentration of soluble fertilizers should be avoided. For example, suppose the average osmotic pressure of a plant is five atmospheres. Suppose a grower applies a large amount of readily soluble fertilizer to the soil occupied by the roots. The readily soluble fertilizer will markedly increase the osmotic pressure of the soil solution. This osmotic pressure may become greater than that of the root hair. What happens to the water in the protoplasm? Does this happen in agricultural practice? Explain.

The *cortex* consists of relatively large, nearly rounded, thin-walled parenchyma cells. In the root hair zone this tissue serves as a system for the diffusion of water and nutrients from the root hairs to the endodermis.

The *endodermis* consists of a single layer of specialized parenchyma cells. In the root hair zone its radial and transverse walls are impregnated with a layer of oxidized fat called suberin. Suberin, in common with all fatty substances, is impervious to water and substances in solution with water. Consequently, the radial and transverse walls of the endodermis are impervious to water and solutes. Thus, the water and solutes can only go through the protoplasm.

The *pericycle* consists of a single layer of cells and the *vascular bundles* consist of radially arranged primary phloem and primary xylem. Note that this radial arrangement allows the water and nutrients to pass directly to the primary xylem without going into the primary phloem. The *xylem provides a channel for the transportation of water and nutrients, and the phloem provides a channel for the passage or translocation of foods*—the carbohydrates, proteins, fats, and related substances.

The Region of Lateral Root Formation and Further Differentiation. This region occurs just back of the root hair zone. In this region the walls of the epidermis, cortex, and endodermis increase in thickness and become impervious to water. Thus, this region is useless for water and nutrient absorption. When lateral roots are formed, the cells of the pericycle divide and form a growing point. This growing point passes through the endodermis, cortex, and epidermis and into the soil. Thus, *the function of the pericycle in this region is the formation of lateral roots.* Figure 5 is a cross-section of the root in the root hair zone. Note the position, thickness, and structure of the cells of each tissue.

The region of growth in diameter consists of that part of the root system from the region of growth in length to the base of the stem. Growth in diameter is due to the activity of meristematic tissues called: (1) The vascular cambium and (2) the cork cambium or phellogen.

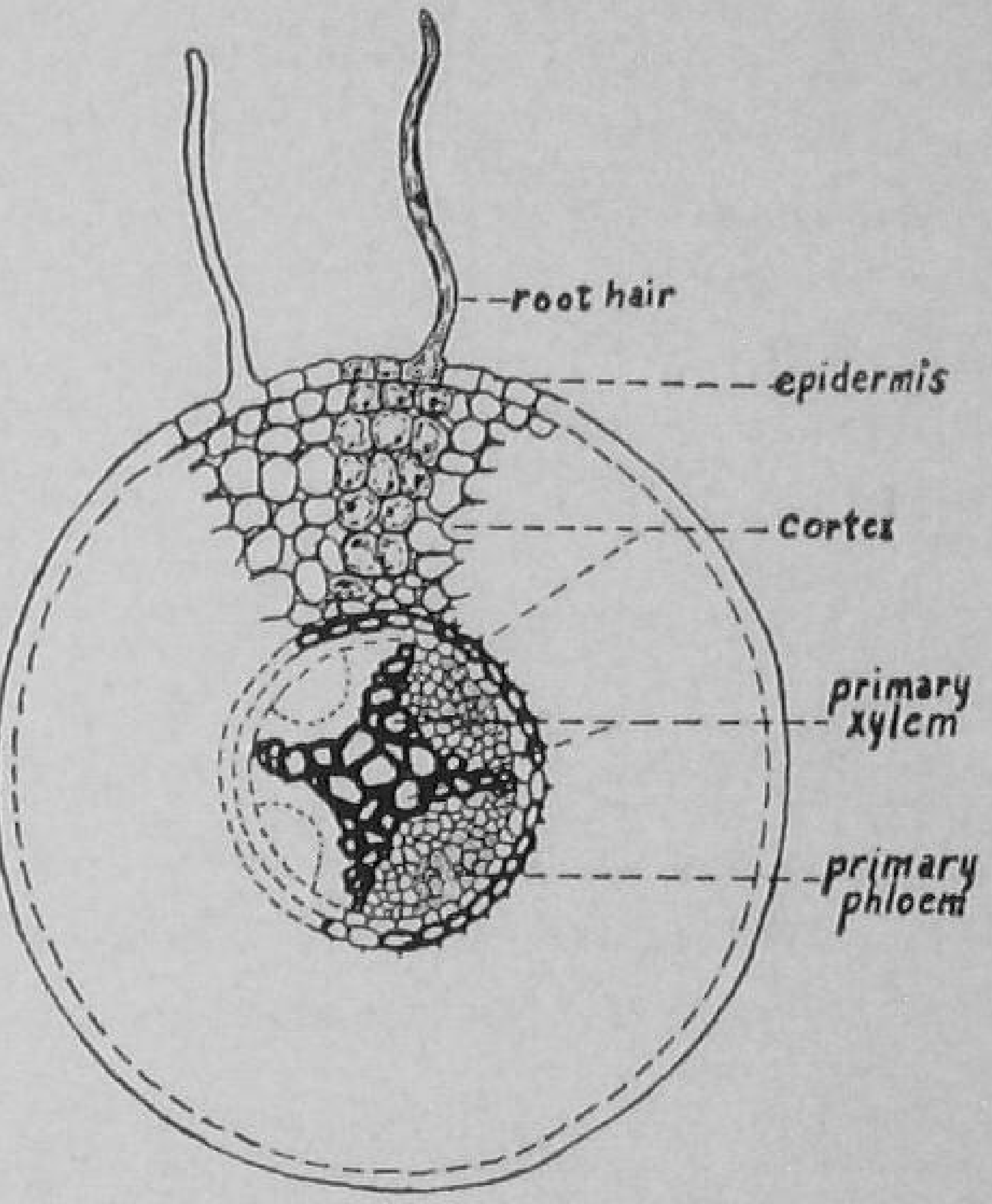

FIG. 5. Cross-section of a root in the root hair zone. (Redrawn by permission from Coulter, M. C.: "The Story of the Plant Kingdom," Chicago, University of Chicago Press.)

The *vascular cambium* is derived from certain parenchyma cells between the primary phloem and the primary xylem. The cambium divides and forms new cells and these cells differentiate into three distinct tissues: (1) Secondary phloem, (2) secondary xylem, and (3) medullary rays. In woody plants the secondary phloem and secondary xylem take over the functions of the primary phloem and the primary xylem. The medullary rays are arranged between the vascular bundles in the same way as the spokes in a wheel. In these rays foods are stored and translocated radially.

The *cork cambium* develops from certain cells in the pericycle or cortex. This cambium divides and gives rise to a layer of cork. Since cork cells are impervious to water, the secondary root is useless as a water-absorbing

organ. Thus, its chief function is support and the storage of food. Table 1 presents the analogous tissues of the primary root and the secondary root.

Table 1

ANALOGOUS TISSUE OF THE HERBACEOUS (PRIMARY) ROOT AND THE WOODY (SECONDARY) ROOT

Herbaceous (Primary) Root		*Woody (Secondary) Root*	
Tissue	*Function*	*Tissue*	*Function*
Epidermis	Water and nutrient absorption	Cork	Protection and gaseous exchange
Cortex	Protection, diffusion, storage		
Endodermis	Prevents excessive leakage of water and sugars in root hair zone		
Pericycle	Produces lateral roots	Cork cambium .	Cell division, growth in thickness
Primary phloem	Food conduction	Secondary phloem	Food conduction
Growing points .	Cell division, growth in length	Cambium	Cell division, growth in thickness
Primary xylem .	Water and nutrient conduction	Secondary xylem	Water and nutrient conduction
Pith	Storage	Medullary rays .	Conduction and storage

Modified Roots. Modified roots have the same anatomy as ordinary roots except that certain tissues have become enlarged or modified for some particular function. A prime function of enlarged modified roots is the storage of foods. Examples are the roots of sweetpotatoes, dahlias, and asparagus and the lower part of the edible portion of carrots, beets, radishes, turnips, rutabaga, and horseradish. Note the fleshy roots shown in Figure 6.

FUNCTION OF ROOTS

The primary function of the root system is the absorption of water and nutrients. Other functions are: holding the plant in place; conducting water, nutrients, and foods; and storing carbohydrates.

As previously stated, the root system increases in length by division and enlargement of the cells at the tip, and increases in thickness by division

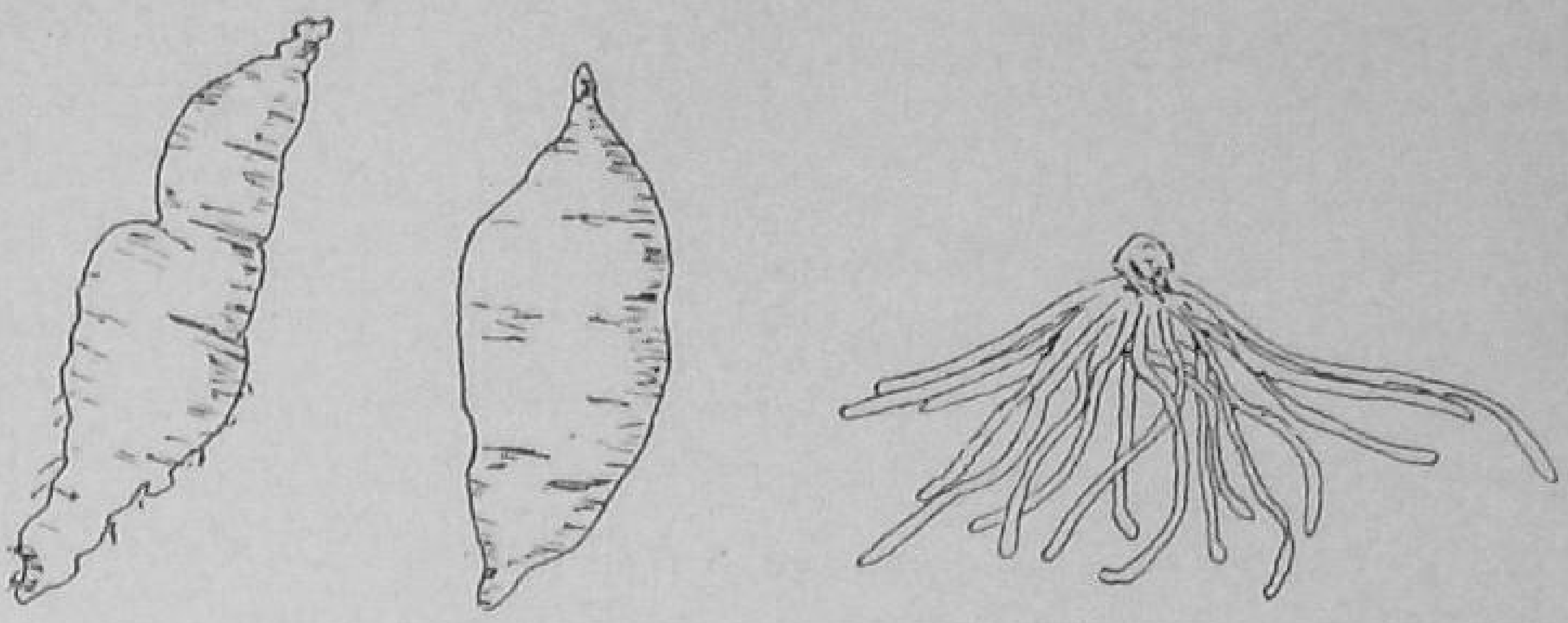

FIG. 6. Examples of fleshy roots. (*Left*) Dahlia. (*Center*) Sweetpotato. (*Right*) Asparagus.

of the vascular and cork cambium. For these processes the cambiums require large quantities of manufactured foods—the carbohydrates, fats, and proteins—and abundant water. Since the carbohydrates are manufactured in the leaves, the growth of the root is dependent on the health and abundance of the leaves. In other words, a plant with a relatively small top will possess a relatively small root system. Conversely, a plant with a large top will have a large root system. For these reasons, pruning, mechanical, disease, or insect injury to the tops will correspondingly retard the growth and development of the roots.

THE STEM SYSTEM

Like the root system, the stem system of higher plants may be divided into two more or less distinct parts: (1) That part which grows in length and (2) that part which grows in diameter. These parts in turn may be divided into various regions, according to the particular function which each part performs.

GROWTH IN LENGTH

The part of the stem system which grows in length is divided into three distinct but overlapping regions: (1) Cell division, (2) cell elongation, and (3) cell differentiation.

The Region of Cell Division. This exists within the buds of stems. Buds are really undeveloped stems. Groups of meristematic cells are found at the nodes and terminal portions of these young stems. When buds are expanding and growing, the meristematic cells are dividing. In fact, the rate of stem elongation depends largely on the rate of division of these cells.

The Region of Cell Elongation. This exists from the base of the buds downward through several nodes and internodes. Like the region of elongation in the root system, it consists of meristematic cells which have developed large vacuoles for the absorption of abundant quantities of water. This absorption of water stretches the cells lengthwise and thus elongation takes place. As in the case of the root system, the student should remember that large quantities of sugars are necessary for cell elongation.

The Region of Cell Differentiation or Maturation. This region consists of the remainder of the stem which grows in length. In this region, differentiation into distinct tissues takes place. These tissues are: (1) Epidermis, (2) cortex, (3) pericycle, and (4) vascular bundles.

The *epidermis* of herbaceous stems consists of two distinct cell types: (1) Protective and (2) guard. The *protective cells* have thick radial walls and toothed or flanged tangential walls. The outer walls contain a layer of wax. The function of these protective cells is to keep water within the plant and to guard against injury. The thickening and dovetailing of the walls and the development of wax and hairs on the outer wall combine to reduce transpiration. The *guard cells* exist in pairs, contain chlorophyll, and thus manufacture food. The inner walls are next to an opening, the stomate, through which gases, carbon dioxide, oxygen, and water vapor diffuse. When the guard cells are collapsed, the stomata are closed and gaseous diffusion is prevented. How do we know when the guard cells are collapsed? As previously stated, a relatively high concentration of sugars in the guard cells is necessary to keep them fully stretched. A decrease in water supplies on one hand and a lack of sugar manufacture on the other decreases the size of the cells. This decrease in size of the guard cells decreases the size of the stomata which in turn decreases the diffusion of carbon dioxide into the plant. Thus, carbon dioxide assimilation or photosynthesis is decreased and yields are likely to be low.

The *cortex* consists mostly of protective cells. If the cortex is green, it makes sugars; if not green, it stores sugars, usually in the form of starch. In old herbaceous stems fibers are usually present in this tissue.

The *pericycle* consists of one or several layers of cells. If it consists of several layers, it contains both food-storing tissue and strengthening tissue. The fibers may exist in isolated groups or in a continuous ring. The amount of fiber in stems has an important relation to the quality of certain vegetables. For example, old asparagus spears contain more strengthening tissue than young spears; hence they are lower in quality.

The *vascular bundles* consist of (1) primary phloem, the food-conduct-

ing tissue and (2) primary xylem, the water-conducting tissue. In the stem of dicots, the vascular bundles exist in the form of a ring; in the stem of monocots, they are scattered throughout the tissues. The *medullary rays* consist of thin-walled cells. They are located between the vascular bundles in much the same way as the spokes of a wheel. In these rays foods are stored and translocated radially. The *pith* consists of thin-walled parenchyma, usually with intercellular spaces. The function of the pith is to store food. Figures 7A and 7B show a cross-section of the stem of a monocot and the stem of a dicot. Note the differences in arrangement of the vascular bundles.

GROWTH IN DIAMETER OR THICKNESS

The region of growth in diameter consists of that part of the stem from the region of cell elongation to the place where the stem joins the root system. As is the case of the root, growth in thickness of the stem is due to the activity of meristematic tissues called (1) the cambium and (2) cork cambium or phellogen. The cambium is derived from the procambium and gives rise to *secondary phloem, secondary xylem,* and *medullary rays.* This secondary phloem and secondary xylem take over the work of the primary phloem and primary xylem in woody stems. The cork cambium is derived from a layer of cells in the cortex. These cells revert to the meristematic condition, divide tangentially, and produce the layer of cork. Thus, the anatomy of the woody stem and the woody root are similar.

Table 2 presents analogous tissues and functions of the dicotyledonous herbaceous primary stem and the dicotyledonous secondary woody stem, and Figure 8 shows the arrangement of the tissues before the development of annual rings in the woody stem.

Modified Stems. Modified stems have the same anatomy as ordinary stems except that certain tissues have been modified for some particular function. Modified stems may be classified as: (1) Underground stems, (2) climbing, twining, or creeping stems, and (3) food-making stems.

Underground stems develop in the soil or in darkness and because of this they are often erroneously called roots. Their function is the storage of food. Examples are the tubers of the potato and the Jerusalem artichoke.

Climbing stems develop roots or tendrils which attach themselves to objects. Examples are English ivy, Climbing Hydrangea, grape, cucumber, and Boston ivy. *Creeping stems* trail on the surface of the soil and often produce roots at the node. Examples are the sweetpotato and squash.

Food-manufacturing stems take the place of the leaves in photosynthesis. Examples are *Asparagus plumosus*, garden asparagus, and cacti. In asparagus the leaves are small, triangular, nonfunctional structures, and in cacti the leaves are the spines on the fleshy, green stems. Note the modified stems in Figure 9.

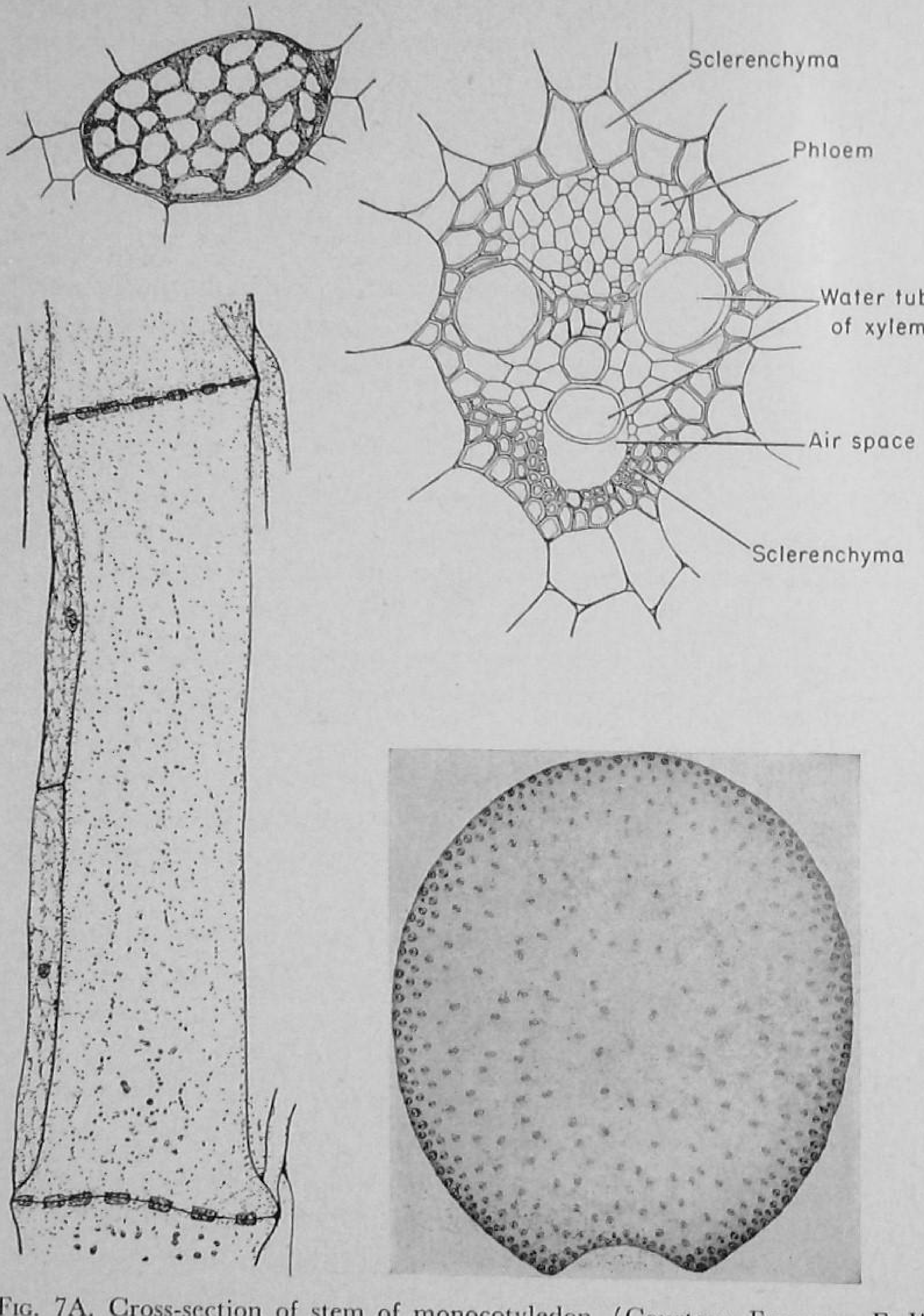

FIG. 7A. Cross-section of stem of monocotyledon. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

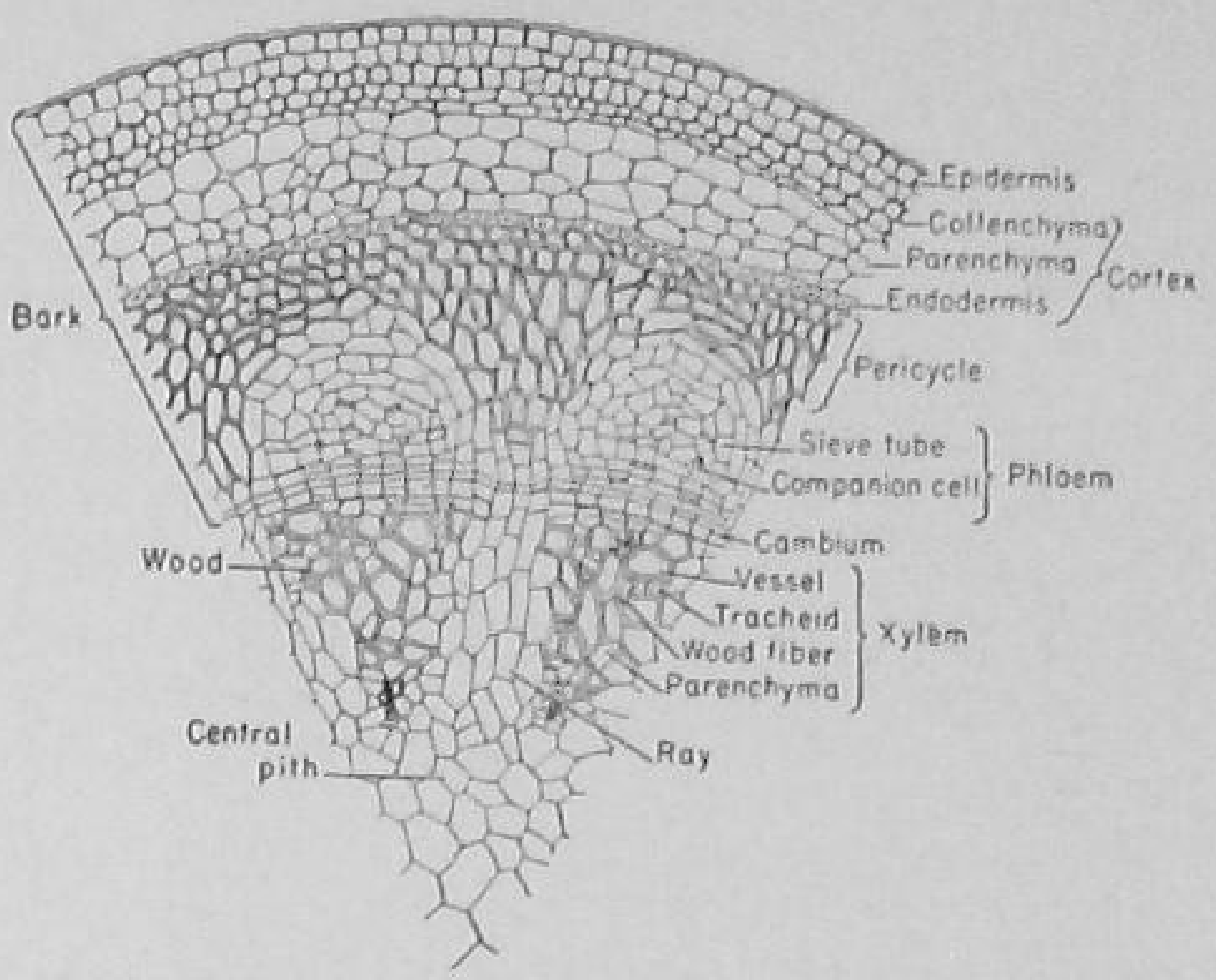

FIG. 7B. Cross-section of stem of dicotyledon. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

Table 2

ANALOGOUS TISSUES OF THE HERBACEOUS (PRIMARY) STEM AND THE WOODY (SECONDARY) STEM

Herbaceous (Primary) Stem		*Woody (Secondary) Stem*	
Tissue	*Function*	*Tissue*	*Function*
Epidermis	Protection and gas exchange	Cork	Protection and gas exchange
Cortex	Protection, storage, and support	Cork cambium .	Cell division, production of cork cells
Endodermis .... (not always present)	Storage		
Pericycle	Storage and support produces roots on cuttings	Pericycle ...... (not always present)	
Primary phloem.	Food conduction	Secondary phloem	Food conduction
Procambium ...	Cell formation	Cambium	Cell formation—production of secondary phloem and secondary xylem
Primary xylem .	Water and nutrient conduction	Secondary xylem	Water and nutrient conduction
Pith	Storage	Medullary rays and pith	Food storage and conduction

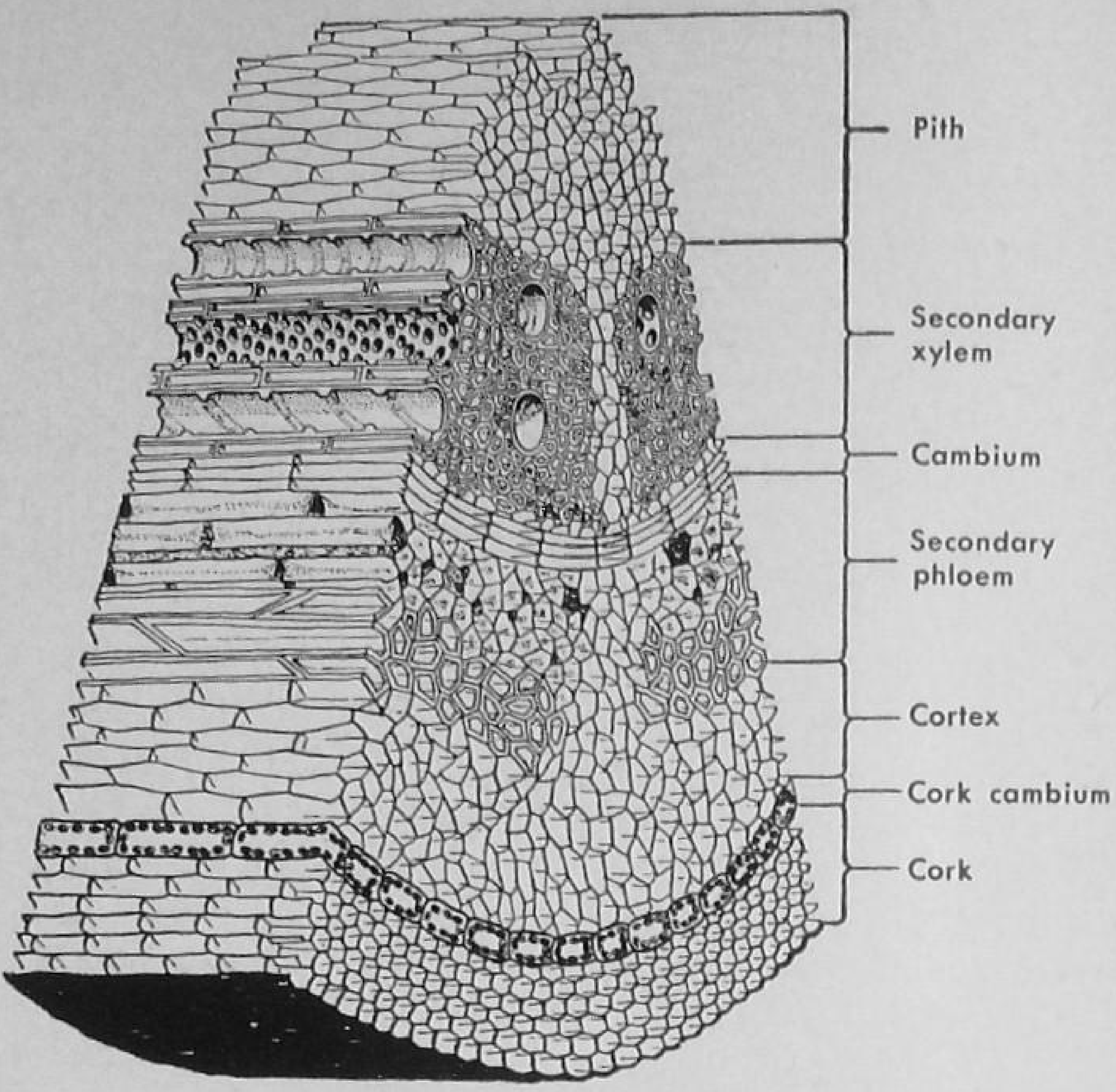

FIG. 8. Cross-section of a sector cut from a dicot stem. This stem is diagrammatic for a herbaceous plant, showing a well-defined green cork cambium and central pith.

FUNCTION OF STEMS

The primary function of the stem is the holding of the leaves in the light and the transporting of water and nutrients from the roots to the leaves and of food from the leaves to various parts of the stem and to the root. A secondary function is storage of manufactured food.

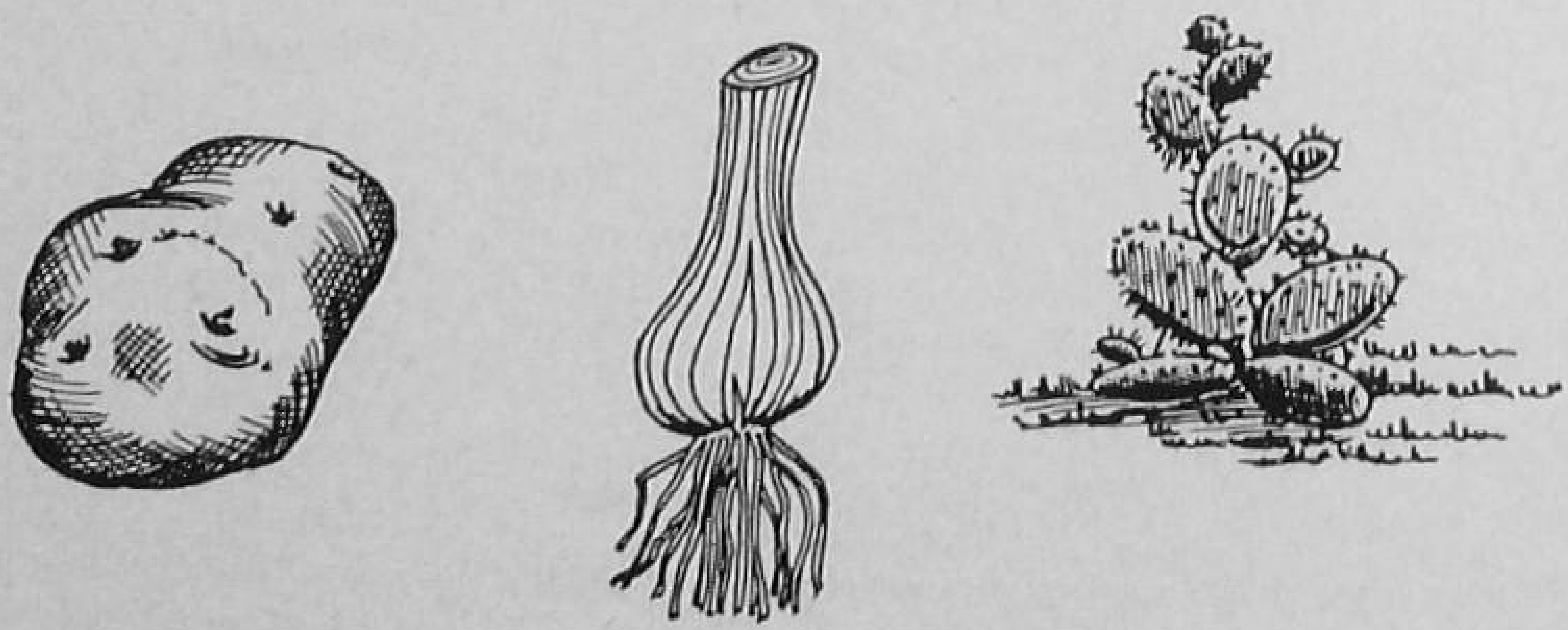

FIG. 9. Examples of modified stems. (*Left and center*) Storage. (*Right*) Food making.

Questions

1. Name the principal plant structures.
2. Name the regions of growth in length of the root system.
3. What is a root hair? What is its function?
4. If the roots of plants are exposed to sunshine and wind, the plant's recovery from the check in growth incident to transplanting is retarded. Explain.
5. Within the same kind or variety, plants with a large top have a large root system and those with a small top have a small root system. Explain.
6. To what extent is: the root dependent on the top? the top dependent on the root? Explain.
7. What is the primary function of the root system?
8. Name the regions of growth in length of the stem system.
9. What is a guard cell? Draw a surface view of a guard cell with adjoining epidermal cells. Label all parts.
10. Show how decreasing supplies of sugar and water in the guard cells will induce closing of the stoma.
11. In general, the longer the stomata are open during the day, the longer photosynthesis takes place and the greater yield. Explain.
12. The training of tomatoes to stakes requires tying the string loosely around the stem and stake. Explain.
13. What tissue makes up the greater part of the woody stem?
14. Name the tissues from which the woody stem arises.
15. A nail partially driven into a young tree soon becomes entirely embedded. Explain.
16. Suppose that when you were 15 years old you carved your initials on a 15-year-old tree 5 feet from its base. Would your initials be at the same or at a greater height when you and the tree are 30 years old? Explain.
17. What is the function of the medullary rays?
18. What is the primary function of the stem system?
19. Name: two horticultural crops grown for their fleshy roots; two grown for their fleshy stems.

The Leaves

Leaves are modified stems designed primarily for the purpose of manufacturing food. An individual leaf consists of two parts: (1) The blade and (2) the petiole.

The Blade. The blade may be in one piece called a simple leaf or in several pieces called a compound leaf (see Figure 10). The leaves of most crops are extremely flat and broad. This broadening permits abundant absorption of carbon dioxide and light and facilitates the manufacture of

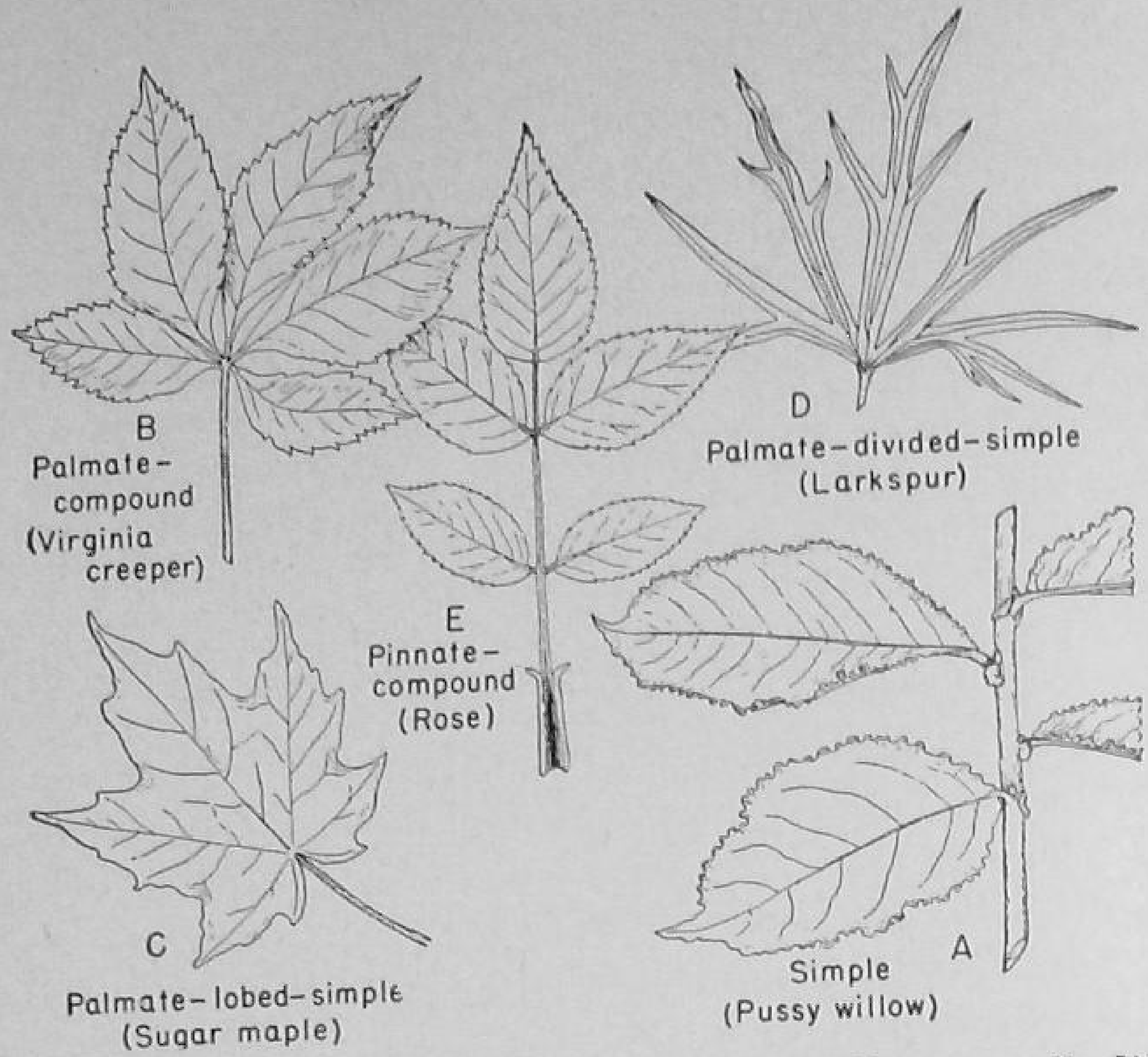

FIG. 10. Simple and compound leaves. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

carbohydrates. The principal tissues of the blade are: (1) The upper and lower epidermis, (2) the palisade and spongy tissue, and (3) the vascular bundles called veins. The position, type of cell, and arrangement of these tissues are presented in Figure 11.

THE UPPER AND LOWER EPIDERMIS. The upper and lower epidermis

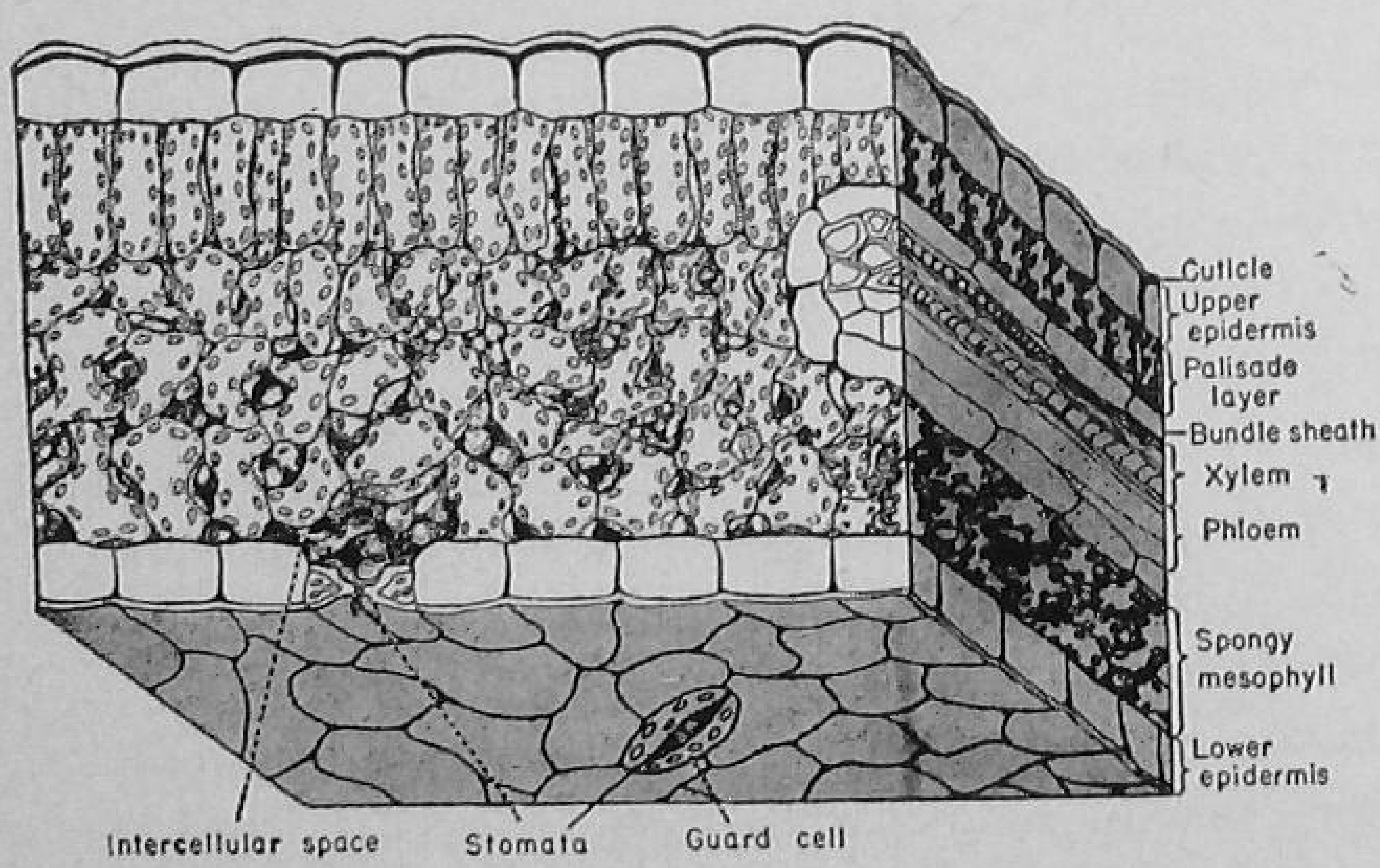

FIG. 11. Three-dimensional section of a leaf of a dicot. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

consist of a single layer of cells. This layer is made up of protective cells which may or may not be interspersed with guard cells. In general, the guard cells occur in the lower epidermis only in fruit crops; and in both epidermis in herbaceous crops. Study the data in Table 3. Note that crops with guard cells on both sides have more in the lower epidermis than in the upper. Can you think of any reason for this?

Table 3

NUMBER OF STOMATA IN THE EPIDERMIS OF CERTAIN HORTICULTURAL PLANTS

Plant	*Number of Stomata Per Square Millimeter*	
	Upper Epidermis	*Lower Epidermis*
*apple	0	294
*peach	0	225
*cabbage	141	226
*potato	51	161
†begonia	0	40
†geranium	19	59

*Miller, F. C.: "Plant Physiology," New York, McGraw-Hill Co., 1931.
†Eckerson, S. F.: The number and size of stomata, *Bot. Gaz.*, 46:221–23, 1908.

The *protective cells* are colorless and have thick radial, toothed, and flanged tangential walls just like those of the stem. The outer wall often contains a layer of wax called the cuticle. The thickness of these walls, combined with the layer of wax on the surface, greatly reduces the rate of transpiration through the protective cells. In fact, investigations have shown that under conditions of high transpiration, only from 1 to 2 per cent of the enormous quantities of water transpired from the leaves is lost through the protective tissue. In other words, by far the greater quantity of water is transpired through the open stomata. In many plants the upper or lower surface of the leaf or both surfaces are covered with hairs. These hairs reduce the transpiration rate.

The *guard cells* of the leaf are similar to those which occur in the herbaceous stem. The student will recall that the guard cells contain chlorophyll; thus, they manufacture food. The walls of these cells vary in thickness and the inner walls are next to an opening, the stomate, through which gases, carbon dioxide, oxygen, and water vapor diffuse. Because of the varying thickness of the walls and because the walls can be stretched, changes in size and shape of these guard cells change the size of the pore. Thus, since the primary function of the leaf is the manufacture of food and since the stomata must be open for the entry of carbon dioxide,

the behavior and occurrence of the guard cells and stomata of the leaf assume great practical significance.

The principal environmental factors which influence the size and shape of these guard cells, which in turn influence the opening and closing of the stomata, are: (1) Light and (2) water supply.

LIGHT. Investigations have shown that with most crop plants light directly influences the opening of the stomata. In other words, when light is available and the water supply is favorable, the stomata are usually open. Conversely, when light is absent the stomata are closed.

How does light influence the size and shape and turgidity of the guard cells? Investigations have shown that changes in size and shape are due to the osmotic pressure within the cells. When the osmotic pressure is high, water is withdrawn from the adjacent cells. As a result, the guard cells increase in size and because of the differential thickness of the walls they also change in shape. These changes in turn increase the size of the pore. Thus, when the guard cells are turgid the stomata are open and the diffusion of carbon dioxide for photosynthesis can take place. Conversely, when the guard cells are flaccid the stomata are practically closed and little, if any, diffusion of carbon dioxide takes place.

With many horticultural crops the stomata are opened during the day and closed during the night. How are the stomata opened in the morning? Two explanations are presented herewith. The first and oldest is based on the manufacture of sugars in the guard cells. In the morning the osmotic pressure of the guard cells is low. The light begins the manufacture of food. This increases the osmotic pressure of the cells. In this way water is withdrawn from the adjacent cells. The guard cells increase in size and the stomata open. At night, because of the absence of light, sugar manufacture does not take place. The osmotic pressure within the cells decreases, water is withdrawn, and the stomata close. The second explanation is based on the hydration and dehydration of colloids within the guard cells. Light causes certain colloids to imbibe water. This in turn induces stretching of the guard cells. During the night these colloids lose their capacity to imbibe water. Thus, the imbibitional capacity of the cells decreases and the stomata close.

WATER SUPPLY. Investigations have shown that with many horticultural plants, apples, peaches, and pecans, when a water deficit occurs within the plant, even in the presence of light the stomata close. This deficit occurs when the income of water through the root hairs is less than the outgo of water through the leaves. As a result the water supply within the plant

decreases and the guard cells, because of their readily pliable, easily stretchable walls, respond to this decrease in the water supply. Thus, with a decrease in the supply of water, the guard cells decrease in size and change in shape, which in turn decreases the size of the stomata. This in turn decreases the amount of water getting out of the plant. However, it also decreases the amount of carbon dioxide getting into the plant. With this decrease in carbon dioxide getting into the plant, a decrease in the rate of photosynthesis takes place which correspondingly decreases the rate of sugar manufacture and correspondingly decreases growth and yield.

THE PALISADE AND SPONGY TISSUE. The palisade cells lie next to the upper epidermis and are rectangular with the long axis at right angles to this tissue. One, two, or three layers of these cells occur, depending on the kind of plant and the amount of light intensity. In general, plants of the same kind growing in full sunshine possess two or three layers, while comparable plants growing in shade possess only one layer.

The spongy cells lie between the palisade cells and the lower epidermis. They are round and have large intercellular spaces between them. These spaces facilitate the diffusion of carbon dioxide while photosynthesis is taking place. *The palisade and spongy cells are the actual carbohydrate-manufacturing cells.* The chemical factories within the cells are the chloroplasts on the surface of which is the pigment chlorophyll. Obviously, the greater the number of these chemical factories, other factors equal, the greater is the manufacture of food. In general, many plants possess remarkable ability to avail themselves of a greater opportunity for carbohydrate manufacture. For example, take two plants, A and B. Plant A is growing in the shade; plant B is growing in the sun. Both plants are subjected to favorable temperatures and are given adequate supplies of water and nutrients. Plant B will develop more rows of palisade cells and a greater number of chloroplasts within each cell. Because of this greater number of palisade cells and the greater number of chloroplasts within each cell, plant B will make more carbohydrates per unit of time. Thus, plant B will develop the more extensive root system and the greater top and will produce the greater yield (see Figure 24).

THE VEINS. The veins of the leaf are vascular bundles, and are in close contact with the food-manufacturing cells. They transport water and nutrients to the manufacturing cells and conduct the manufactured food from the manufacturing cells.

The Petiole. The petiole or leaf stalk consists mainly of vascular bundles and mechanical tissue. The function of the petiole is to serve as a trans-

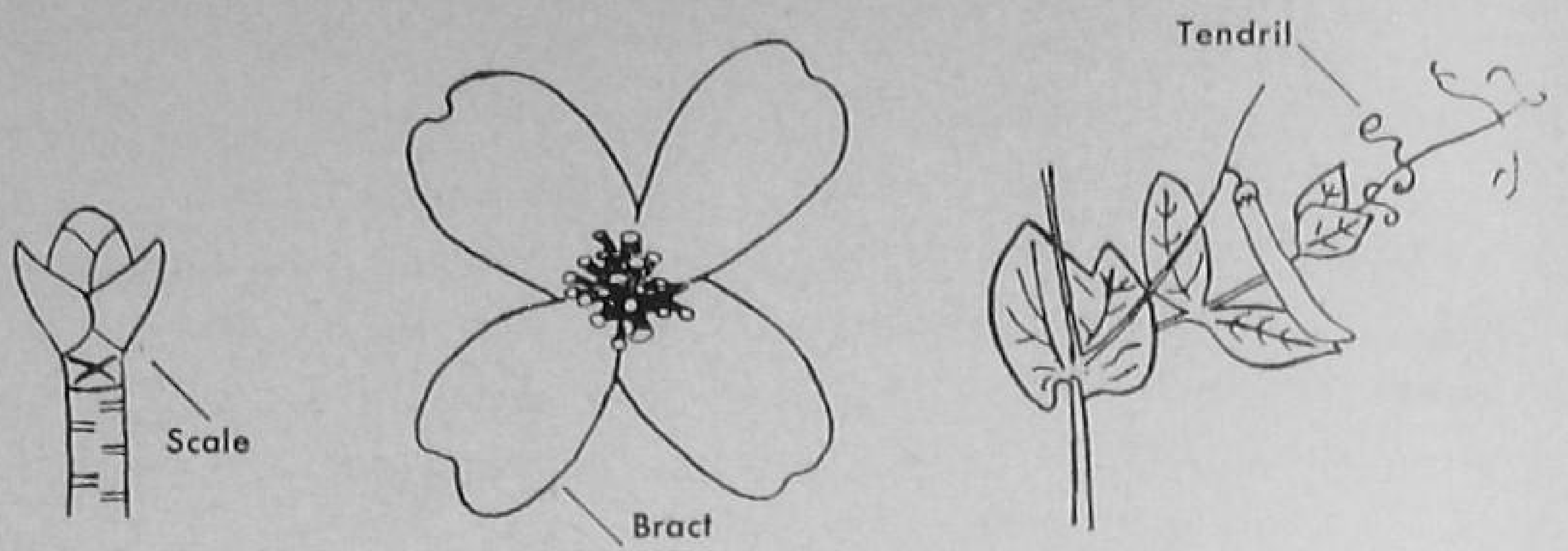

FIG. 12. Types of modified leaves.

portation system between the leaf and the stem and to hold the leaf blade in the light. The petioles of some crops are fleshy and form the edible portion; examples are those of rhubarb and celery.

The Rate of Translocation of Manufactured Sugars. The rate of translocation of manufactured sugars from the leaf greatly influences the rate of photosynthesis. When the rate of translocation is slow, the sugars accumulate in the leaf and the rate of photosynthesis is slowed down. Thus, a slowing down of the development of roots, shoots, flowers, or fruit may correspondingly slow down the rate of sugar manufacture. This, you will recall, is a practical application of the law of mass action.

Modified Leaves. Modified leaves are: (1) Scales, (2) bracts, and (3) tendrils. *Scales* are usually hard, horny structures which protect the buds of woody plants during the winter. *Bracts* are either leafy or fleshy. With some plants they take the place of petals, as in dogwood, poinsettia, and bougainvillaea; with others they become fleshy and are used as food, as in Globe artichoke. *Tendrils* are slender, thread-like structures which possess the ability to twine around objects. For example, the upper leaflets of the compound leaves of the garden pea have been modified to form tendrils. The lower leaflets function as true leaves. Note the modified leaves in Figure 12.

THE FLOWERS

An individual flower consists of groups of modified leaves, arranged concentrically, designed for the purpose of sexual reproduction or reproduction by seed. These groups of modified leaves are: (1) Sepals, (2) petals, (3) stamens, and (4) pistils. Each group has a specific function.

The *sepals* and *petals* protect the delicate stamens and pistils when the flower is in the bud stage. In opened flowers the petals vary greatly in size, number, arrangement, and color. From the standpoint of the plant petals attract insects which carry pollen, and from the standpoint of the human race they are used to beautify the environment.

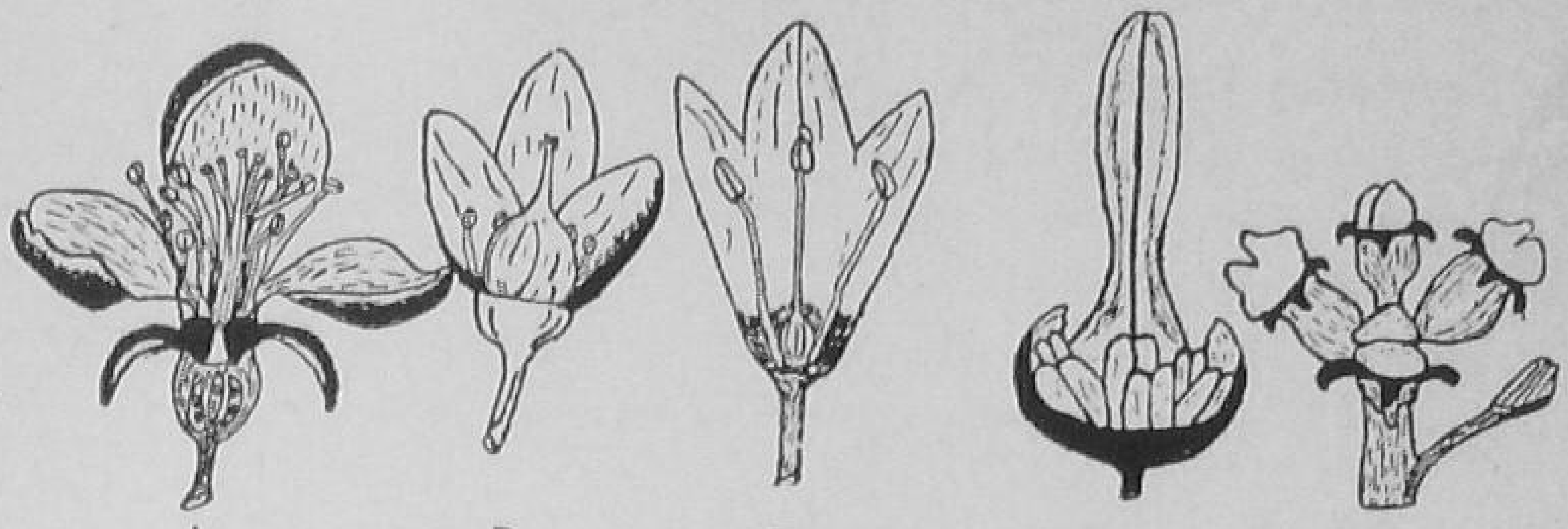

FIG. 13. Examples of perfect, staminate, and pistillate flowers. (A) Perfect flower of apple. (B–C) Pistillate and staminate flowers of asparagus. (D–E) Staminate and pistillate flowers of pecan.

An *individual stamen* consists of a stalk called the filament and a pollen sac called an anther. The function of the stamen, particularly the anther, is to produce pollen which in due time contains sperms. For this reason the stamens are called the male organs of the plant.

An *individual pistil* consists of an ovary, style, and stigma. The ovary is the enlarged portion at the base of the pistil, the stigma is the flattened portion at the apex, and the style is the connecting tissue between the two. The function of the pistil, particularly the ovary, is to produce one or more ovules, each of which in due time contains, with other cells, an egg. For this reason the pistil is called the female organ of the plant.*

TYPES OF SEX EXPRESSION

Type of sex expression is based on the presence of both the stamens and pistils in the flowers of any particular plant and on the absence of either one of these organs: (1) If stamens and pistils are present in the same flower, the plant is a hermaphrodite; (2) if the stamens and pistils are in separate flowers in the same plant, the plant is monoecious; and (3) if the stamens and pistils are in separate flowers in separate plants, the plant is dioecious. Examples of each type follow:

Hermaphroditic Plants. Apple, pear, peach, plum, Labrusca grape, raspberry, blackberry, strawberry, gooseberry, cranberry, citrus crops (lemon, orange, grapefruit), avocado, almond, cabbage, radish, carrot, celery, sweetpotato, tomato, pepper, eggplant, bean, pea, okra, rose, chrysanthemum, carnation, violet, sweet pea, and snapdragon.

*The authors are aware that morphologists regard the monoploid generation as "sexual" and the diploid generation as "nonsexual." In this text both generations are considered one entire life cycle, and the pistil is considered the female organ and the stamen the male organ.

Monoecious Plants. Pecan, walnut, filbert, chestnut, tung, cucumber, cantaloupe, pumpkin, squash, watermelon, and sweet corn.

Dioecious Plants. Persimmon, Muscadine grape (certain varieties), date, spinach, asparagus, and holly.

Figure 13 shows the hermaphroditic flowers of apple and the pistillate (female) and staminate (male) flowers of asparagus and pecan.

Questions

1. What is the primary function of the leaves?
2. Draw from memory a diagram of the tissues of a leaf showing: the upper and lower epidermis, the palisade and spongy tissue, the veins, the guard cells, the stomata.
3. When the stomata are closed the plant is not making carbohydrates. Explain.
4. What are the functions of the leaf petiole?
5. In the leaf petiole the corners of certain cells are much thickened. Explain.
6. What is the principal function of the flower?
7. Name the parts of a flower and give the function of each.
8. What part of the plant produces: pollen? ovules?
9. Name the different ways in which the sex organs of plants are arranged.
10. Draw: a hermaphroditic flower, a staminate flower, a pistillate flower. Label all parts.
11. Staminate flowers do not produce fruit, yet they are essential for fruit and seed production. Explain.
12. Monoecious and dioecious crops require pollen-carrying agents for the production of fruit and seed. Explain.

Assignment 3

The Fruit and Seed

POLLINATION

Many plants are grown for their fruits or seeds or for both fruit and seeds. With these plants the development of the fruit and seed depends on the successful union of the sperms and eggs and the subsequent growth of

the embryos. Since the egg cells of plants remain within the ovules, the sperms of plants must go to the eggs. With many plants the journey of an individual sperm to an individual egg is not an easy one. Instances are frequent in which the sperm fails to reach the egg. Sometimes the pollen which carries the sperm is not transferred to the stigma of the pistil; sometimes the weather retards or prevents the germination of the pollen; sometimes the rate of growth of the pollen tube down the style is so slow that the egg dies before the sperm arrives. To more fully understand some of the difficulties met by the sperm, its journey to the egg is considered in two stages: (1) The transfer of pollen and (2) growth of the pollen tube down the style to the embryo sac.

The Transfer of Pollen. *The transfer of pollen from the anther of the stamen to the stigma of the pistil is called pollination.* Four general methods of pollen transfer are used: (1) By the force of gravity, (2) by contact, (3) by wind, and (4) by insects. Pollen transfer *by the force of gravity* or *by contact* usually takes place when the pistil(s) and stamens are in the same flower. The force of gravity is effective when the flower is in the pendent position and the stigma extends beyond the anthers, while transfer by contact is effective when the stamens, as they elongate, shed their pollen when the anthers come in contact with the receptive stigma. Pollen transferred *by wind* or *by insects* is necessary when the pistil and the stamens are in different flowers or when, for some reason, the stamens fail to pollinate the pistil in the same flower.

Wind- and insect-pollinated crops present somewhat different problems in respect to adequate pollination. Pollen transferred by wind is subject to chance currents of air. Thus, it lacks directness; large quantities of pollen are necessary; and the grower should know how far such pollen is carried. On the other hand, pollen transferred by insects is more direct, and lesser amounts of pollen are necessary. Thus, wind- and insect-pollinated plants have marked differences in adaptation to pollination. In general, wind-pollinated plants have inconspicuous flowers, produce small, dry pollen in large quantities, and possess long, branched, or feathery styles in order to catch the pollen grains. On the other hand, insect-pollinated plants have large, highly colored petals or bracts, produce large, sometimes sticky, pollen, and possess well-developed nectaries. These nectaries secrete sugars and other substances for the attraction of insects. They are so situated that, when insects visit the flowers, their bodies which carry the pollen come in contact with the stigma. The principal insects are certain species of bees, most important of which is the honeybee.

THE HONEYBEE. The needs and the physical equipment of the honeybee are well adapted for the work of pollination. The body is covered with numerous hairs to which the pollen clings and their action on the flower is gentle. Thus, the delicate tissues of the pistil are not injured. Important environmental factors affecting the activity of honeybees are: (1) The temperature of the air and (2) the food (nectar and pollen) supply. Investigations have shown that honeybees are comparatively inactive at temperature lower than 50° F. and cannot use their wings at temperatures lower than 40° F. Consequently, honeybees do not fly very far in cool weather. To help the bees perform the task of pollination of many crops, growers distribute colonies of bees throughout the orchard, greenhouse, or plantation. Figure 14 shows a honeybee visiting a cucumber flower. Cucumbers are monoecious, the pollen is large and sticky, and the honeybee is the chief agent of pollination.

The production of honeybees for pollination purposes in the many orchards throughout the country is an important industry. For the most part this industry is located in the South where the winter season is comparatively mild. These bees are shipped in small packages, hence the name "package bees." These packages are placed in advantageous positions in the orchard during the pollinating season. Some authorities have stated

FIG. 14. A honeybee visiting a cucumber flower. (Courtesy, W. S. Anderson, Mississippi State College.)

that honeybees are about 50 times more valuable for their work of pollination in orchards, gardens, and fields than they are for the honey they make.

TYPES OF POLLINATION. There are two types of pollination: (1) Self-pollination and (2) cross-pollination. In horticulture there are two distinct concepts of self- and cross-pollination. These different concepts are due largely to the differences in the behavior of asexually and sexually propagated crops. The varieties of asexually propagated crops, such as those of the apple, peach, citrus, and pecan, are descended from a single plant or a single bud and, unless mutations take place, the plants of any particular variety are identical. For example, all of the apple trees of the Delicious variety are descendants from one original bud. Since the apple is propagated by using pieces of stem or a single stem, the many thousands of Delicious trees in the country are identical with the original tree. Thus, the pollen of all Delicious trees is identical, and in like manner the pollen of any given asexually propagated variety is identical. On the other hand, plants of sexually propagated plants are produced from seed and the plants from the seed may or may not be identical. Thus, the pollen may or may not be identical. In other words, in asexually propagated crops *the variety* is considered the unit, whereas in sexually propagated crops *the plant* is considered the unit. Thus, with asexually propagated crops self-pollination is the transfer of pollen from a flower of one variety to a flower of the *same variety*. The two flowers may be on the same tree or on different trees of the *same variety*. Similarly, cross-pollination is the transfer of pollen from a flower of *one variety* to a flower of *another variety*. On the other hand, with sexually propagated plants self-pollination is the transfer of pollen from the stamens to the pistil within the same flower or between flowers of the *same plant*. Similarly, cross-pollination is the transfer of pollen from the stamens of a flower of one plant to the pistil of a flower of *another plant*. This plant may belong to the same strain or to another variety or even to a related species.

Each type of pollination has its place in horticultural crop production. With asexually propagated plants many varieties of certain crops produce larger and better fruit when they are cross-pollinated. For example, many varieties of the apple and all varieties of the sweet cherry fail to set fruit unless pollen of other varieties is used. These varieties necessary for the pollination of other varieties are called pollinators. Consequently, the choice of a variety for pollination purposes in the orchard of these fruits is particularly important. With sexually propagated crops self-pollination maintains uniformity and reduces variability of any particular strain or

variety.* On the other hand, cross-pollination introduces new characters and increases diversity. A classification of horticultural crops based on type of pollination follows:

SELF-POLLINATED CROPS. Bunch grape (most varieties), peach (most varieties), plum (some European varieties), almond, gooseberry, blackberry, currant, strawberry (most varieties), citrus (most varieties), cherry (sour), tomato, pepper, eggplant, bean, pea, sweet pea, and snapdragon.

CROSS-POLLINATED CROPS: *By Wind.* Pecan, walnut, chestnut, filbert, spinach, garden beet, and sweet corn.

By Insects. Apple, pear, peach (a few varieties), plum (most Japanese and American varieties), cherry (sweet), cabbage, lettuce, onion, carrot, cucurbits, aster, azalea, calceolaria, pansy, and zinnia.

Growth of the Pollen Tube Down the Style. On the surface of the stigma the pollen grain germinates. That is, it produces a slender tube which grows down the style. Factors concerned in the germination of the pollen grain and growth of the pollen tube are: (1) Time and duration of the receptivity of the pistil, (2) temperature, (3) food supply in the stylar tissue, and (4) compatibility of the pollen tube and stylar tissue. The period of receptivity varies with the kind of plant and with weather conditions. In general, the pistils of most crops are receptive from the time the petals unfold to a few hours or several days thereafter. For example, the period of receptivity in pears varies from 2 to 7 days, in apples from 2 to 4 days, in plums from 3 to 5 days, and in watermelons from 1 to 3 hours.

With most plants the time of receptivity coincides with the time of pollen shedding. However, with some crops these two processes do not always take place simultaneously. An example is the pecan. Under certain conditions the stamens of the same variety shed their pollen before the pistils are receptive. This necessitates the planting of at least two varieties in the orchard so that pollen shedding of one variety and pistil receptivity of the other may occur simultaneously. In other words, these processes, pollen shedding and pistil receptivity, should be synchronized.

A low temperature naturally retards the growth of the pollen tube. Thus, when the weather is cold during the pollinating season in the orchard or garden, the set of fruit is likely to be low. Naturally, if the food supply of the tissues of the style is low, the growth of the tube will be correspondingly slow. Of more importance is the compatibility of the pollen. *Com-*

*Some cross-pollination usually takes place in sexually propagated, self-pollinated plants.

patible pollen possesses the ability to grow down the style in time for the sperm to unite with the egg. Incompatible pollen does not possess this ability, even though the temperature and food supply are favorable. With some crops—for example, the apple, sweet cherry, cabbage, and petunia—the pollen of many varieties is self-incompatible. These self-incompatible varieties cannot pollinate their own pistils. Hence, another variety or plant must be used. Such a variety, as previously stated, is known as the pollinator variety.

After germination of the pollen grain, the tube in some plants pushes its way from cell to cell, in others it passes through a channel between the cells, and in any case finally passes through the micropyle and arrives at the embryo sac. Within the embryo sac the tube liberates two sperms. One sperm unites with the egg to form a new plant; the other unites with the endosperm nuclei to form the endosperm. This union of the one sperm with the egg, and the other sperm with the endosperm nuclei, is called *double fertilization.*

FERTILIZATION

Immediately after fertilization, the original egg cell divides and an embryo or young plant is formed. At the same time, the ovary greatly increases in size, and the integuments, the walls of the ovule, expand to make room for the rapidly developing embryo and a large amount of sugars and proteins and water is translocated into the ovary and into the embryo sac(s). These materials are necessary for the maturation of the fruit and for the growth of the embryo(s). Later the embryo(s) stops growing, the ovary ripens or becomes mature, and the walls of the ovule(s) become hard and thick. In this way ripened fruit and mature seed are formed. Thus, *a seed may be defined as a miniature plant with protecting and nourishing structures.*

Classification of Fruits. Fruits of horticultural crops vary greatly in size, shape, color, and chemical composition. In general, they may be classified as fleshy or dry. Fleshy fruits may be further divided into simple and accessory. Simple fruits have developed from ovarian tissue only and accessory fruits have developed from ovarian and adjacent tissue. Dry fruits may be further divided as dehiscent and indehiscent. Dehiscent fruits shed their seed when dry; indehiscent fruits do not. Examples of fleshy and dry fruits are presented in Table 4, and illustrated in Figure 15.

The fruit of some crops develops without fertilization. Examples are: the banana, navel orange, seedless grape, pineapple, and certain varieties

Table 4

TYPES OF FRUITS OF HORTICULTURE CROPS

Fleshy (*High Moisture Content When Mature*)		*Dry* (*Low Moisture Content When Mature*)	
Ovary Tissue Only	*Ovary and Adjacent Tissue*	*Shedding When Mature*	*Not Shedding When Mature*
peach, plum, grape, tomato, pepper, eggplant, raspberry, blackberry, pineapple	apple, pear, strawberry, *fig, cucumber, cantaloupe, pumpkin, watermelon	peas, beans, okra, cabbage, larkspur, peony, lily	celery (seed), carrot (seed), sweet corn

*Most of the flesh consists of peduncle.

of cucumbers. These fruits are called parthenocarpic fruits. Thus, parthenocarpic fruits develop without the aid of fertilization. Recently, scientists have secured parthenocarpic fruits by applying certain chemicals to the stigma of pistils. Examples of the chemicals used are naphthaleneacetic acid and indolebutyric acid.

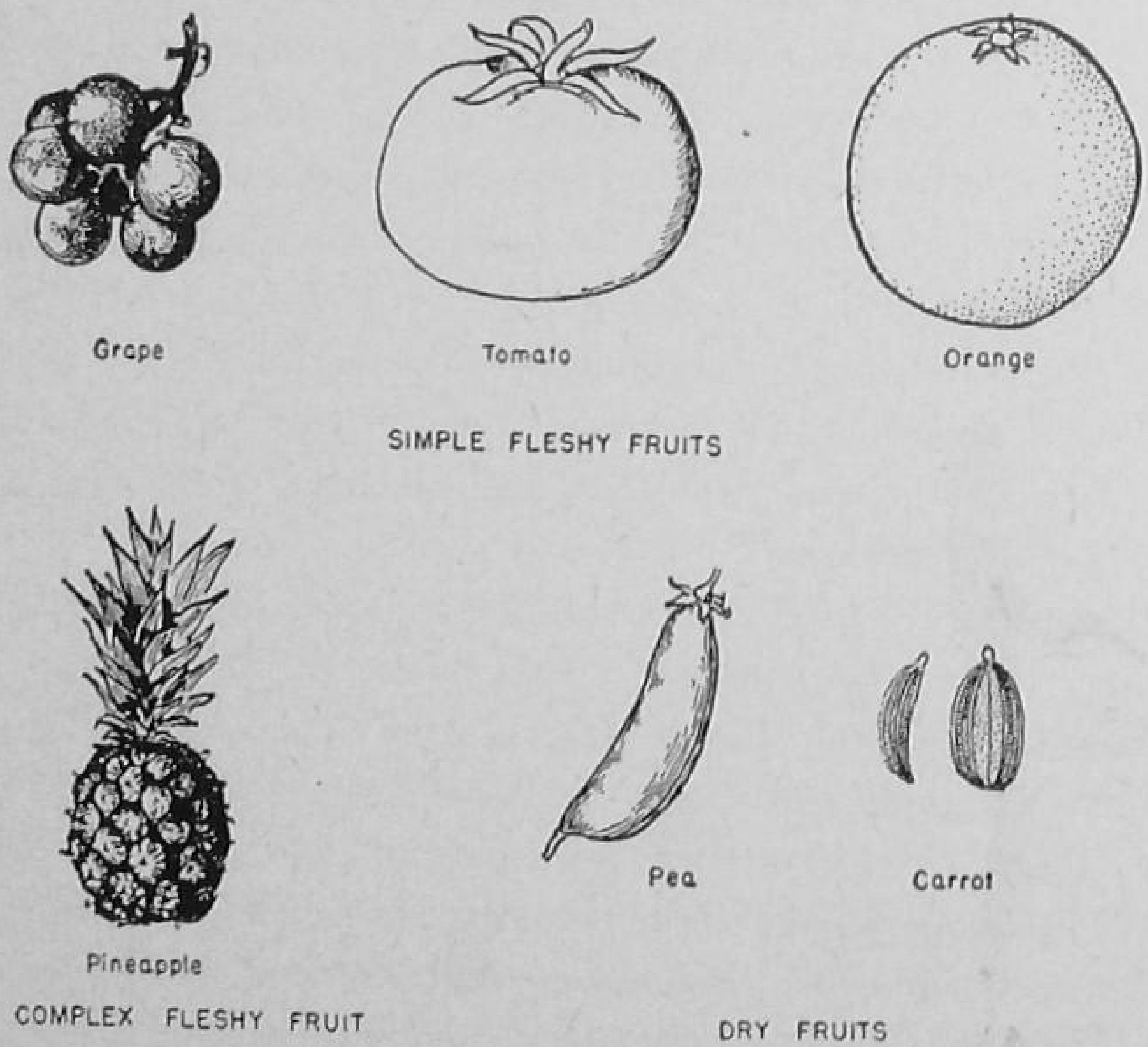

FIG. 15. Fleshy and dry fruits. (Redrawn by permission from Coulter, M. C.: "The Story of the Plant Kingdom," Chicago, University of Chicago Press.)

Questions

1. Define pollination.
2. How do flowers of plants pollinated by wind differ from those pollinated by insects?
3. Growers place bouquets of apple blossoms under the trees during the pollination season. Explain.
4. Observations have shown that frequently the windward side of apple trees possesses less fruit than the leeward side. Can you think of any reason for this?
5. What is meant by: self- and cross-pollination of asexually propagated crops? self- and cross-pollination of sexually propagated crops?
6. With sexually propagated plants it is more difficult to keep seed stocks of cross-pollinated plants "pure" than seed stocks of self-pollinated plants. Explain.
7. What is meant by: compatible pollen? incompatible pollen?
8. What is the main function of a pollinator variety? Pollinator varieties are necessary in apple and sweet cherry orchards. Explain.
9. Large blocks of a single variety of most varieties of peaches can be planted and large crops can be produced. Explain.
10. Six varieties of Muscadine grapes were planted in a vineyard. A very light crop of grapes was produced year after year regardless of cultural practices. What had the grower neglected? Give reasons for your answer.
11. A pecan grower finds that bees in his grove do not increase yields. Explain.
12. What is double fertilization?
13. What is: an immature fruit? a mature fruit?
14. What is the meaning of the term "dehiscent"?
15. Can you think of: any advantages of parthenocarpy? any disadvantages?

2

Phases of Growth and the Carbohydrates

Assignment 4

The growth and development of higher plants consists of two distinct, though overlapping, phases: (1) The vegetative and (2) the reproductive. The vegetative phase consists essentially of the development of the stems, leaves, and absorbing roots. The reproductive phase consists essentially of the development of structures other than the stems, leaves, and roots, —the development of flowers, fruit, seed, fleshy stems, and fleshy roots.

THE VEGETATIVE PHASE

The Vegetative Phase and Carbohydrate Utilization. The vegetative phase of plant development is associated with three important processes: (1) Cell division, (2) cell enlargement, and (3) the initial stages of cell differentiation. *Cell division* consists of the making of new cells. These new cells require large quantities of carbohydrates, since the walls are made of cellulose and the protoplasm is made mostly from sugars. Thus, with other factors in favorable supply, the rate of cell division is dependent on an adequate supply of carbohydrates. As previously stated, cell division takes place within the meristematic tissue, the growing points at the stem and root tips and the cambiums. Therefore, these tissues must be provided with the manufactured foods in order that they can make new cells.

Cell elongation consists of the enlargement of the new cells. This process requires: (1) Abundant supplies of water, (2) the presence of certain hormones which give the cell wall the ability to stretch, and (3) the pres-

ence of sugars. As discussed in Chapter 1, the region of cell elongation occurs just back of the growing points. When the cells in this region begin to enlarge, they develop large vacuoles. These vacuoles absorb relatively large quantities of water. As a result of this absorption of water and the presence of the hormones, the cells elongate, particularly in the lengthwise direction. In addition to this increase in cell size, the walls become thicker, due to the laying down of additional cellulose made from the sugars.

The initial stages of cell differentiation consist of the development of the primary tissues. Their development requires carbohydrates. Examples are the thickening of the walls of the protective cells of the epidermis of the stem, and the development of the conducting tubes of both the root and the stem. Thus, when a plant is making new cells and elongating these cells and laying down its tissues, it is actually developing the stem, leaf, and root system. If the rate of cell division and elongation is rapid, growth of the stems, leaves, and roots will be rapid also. Conversely, if the rate of cell division is slow, growth of the stems, leaves, and roots will be accordingly slow. Since division, enlargement, and tissue formation require a supply of carbohydrates, and since carbohydrates are used in these processes, the development of stems, leaves, and roots requires the utilization of carbohydrates. Thus, *in the vegetative phase of plant development, the carbohydrates are utilized.*

THE REPRODUCTIVE PHASE

The Reproductive Phase and Carbohydrate Accumulation. The reproductive phase consists of the formation and development of flower buds, flowers, fruits, and seed or the enlargement and maturation of storage organs—fleshy stems and fleshy roots. This phase of growth is associated with one important process: the final stages of cell maturation or differentiation.

The final stages of cell maturation are associated with certain physical and chemical changes that occur in the cells after they have reached their size. Manifestations of final differentiation are: (1) The accumulation of sugars, (2) the formation of hormones necessary for the development of flower bud primordia, (3) the laying down of flower buds, (4) the development of fibers and lignin, (5) the storage of reserve carbohydrates, (6) the accumulation of water-holding substances, (7) the development and maturation of fleshy vegetative structures, and (8) the development and maturation of flowers, fruit, and seed. The student will note that all of these manifestations of the reproductive phase of plant development

require a supply of carbohydrates. In most cases these carbohydrates are the sugars and the starches. In other words, when a plant is developing its flowers, fruit, seed, or storage structures, not all of the carbohydrates are being used for the development of the stems, leaves, and roots—some are left for the development of the flowers, fruit, or seed, or for storage. For example, the tubers of the potato, the fleshy roots of the sweetpotato, and the flesh of the apple all contain relatively large quantities of starch and sugars. Thus, *in the reproductive phase of plant development the carbohydrates are stored.*

THE VEGETATIVE-REPRODUCTIVE BALANCE

The vegetative and reproductive phases of plant development may be likened to a balance. One side of the balance may be considered the vegetative phase—the development of stems, leaves, and roots—and the other side may be considered the reproductive phase—the development of flowers, fruit, seed, or storage organs. This concept presents three possible cases: (1) The vegetative phase may be dominant over the reproductive phase—the balance is tipped on the vegetative side; (2) the reproductive phase may be dominant over the vegetative phase—the balance is tipped on the reproductive side; and (3) the vegetative and reproductive phases may be proceeding in equal amounts, both sides of the balance being practically equal. However, the student should guard against obtaining the idea that vegetation can take place without reproduction, or that reproduction can take place without vegetation. If the vegetative phase is dominant with any crop there is always some reproduction. On the other hand, if the reproductive phase is dominant there is always some vegetation. For example, some cell division is necessary for the development of reproductive and storage structures. However, the number of cells necessary for the development of these structures is small compared with the number necessary for the complete development of the stems, leaves, and root system. The term "balance," therefore, refers to a matter of emphasis rather than to the presence or absence of either phase of plant development.

When the vegetative phase of plant development is dominant over the reproductive phase, carbohydrate utilization is dominant over accumulation. More carbohydrates are used than are stored. When the reproductive phase is dominant over the vegetative phase, carbohydrate accumulation is dominant over utilization. More carbohydrates are stored than are used. When the vegetative and reproductive phases are balanced, utiliza-

tion and accumulation are also balanced. In other words, practically equal amounts of carbohydrates are used and stored.

As an example, take three tomato plants—A, B, and C—each of which has grown for a period of 150 days. In plant A the vegetative phase has been dominant over the reproductive phase; in plant B the reproductive phase has been dominant over the vegetative phase; and in plant C both phases have proceeded in practically equal magnitudes.

How would these plants appear? Plant A would be extremely vegetative; that is, there would be an abundant development of stems and leaves. The stems would be succulent, the leaves would be large with little development of cuticle, a wax-like substance on the surface. Flowering and fruiting would not occur or would be suppressed, the cell walls would be thin, and the strengthening tissue would be poorly developed. In other words, most of the carbohydrates had been used for the development of the root system, the stem system, and the leaves. As a result very little of the carbohydrates had been left for the development of flower buds, flowers, fruit, and seed. In this case the vegetative phase had been dominant over the reproductive phase and carbohydrate utilization had been dominant over carbohydrate accumulation.

Extreme vigor of the top combined with a lack of, or reduction in, the development of flowers, fruit, and seed generally take place under the following conditions. The plants are in the early stages of growth. They have a rapid rate of photosynthesis. The temperature favors *a rapid rate of cell division* and water and nutrients are abundant. The large quantity of carbohydrates made combine with the nitrogen compounds to form the protoplasm made in the growing points of the stems and roots. As a result vegetative processes are dominant over reproductive processes.

Plant B would be poorly vegetative and stunted. There would be little development of leaves and stems. The stems would be woody, the internodes would be short, the leaves would be moderately small with good development of cuticle. Flower and fruiting would be evident, the cell walls would be very thick, conducting tissues would be well developed, and storage tissues would be packed with starch. Since stems are necessary to support flowers and fruit, and since in plant B there was relatively less development of stems and leaves, yields would be accordingly low. In this case the reproductive phase had been dominant over the vegetative phase and carbohydrate accumulation had been dominant over carbohydrate utilization.

Weak stunted plants generally result under the following conditions.

The plants have a high or moderately low rate of photosynthesis. The temperature (or the water supply, or the nutrient supply, or some other factor) is *unfavorable for even a moderate rate of cell division.* As a result the carbohydrates accumulate and are used for reproductive processes to a greater extent than for vegetative processes.

Plant C would be moderately vegetative and fruitful. The stems would be moderately succulent, the internodes moderately long, and the leaves moderately large with normal development of cuticle. Flowering and fruiting would proceed simultaneously with the development of stems and leaves. The cell walls would be fairly thick and there would be normal development of the conducting tissues. In this case moderate amounts of carbohydrates had been used for the development of stems and leaves and the remainder had been used for the development of flowers and fruit. Since both the vegetative and reproductive phases lacked dominance, carbohydrate utilization and accumulation lacked dominance also and each phase proceeded in practically equal magnitudes.

Moderate vigor of the top combined with the development of flowers, fruits, or seed generally take place under the following conditions. The plants have a high rate of photosynthesis. The temperature and other environmental conditions favor a *moderately rapid rate of cell division.* As a result not all of the carbohydrates are used for the development of stems and leaves—some are left for the development of flowers and fruit. Vegetative and reproductive processes lack dominance and the plants are moderately vegetative and fruitful.

Thus, the growth of stems and leaves is associated with carbohydrate utilization and the development of flowers, fruit, seed, or fleshy structures is associated with carbohydrate accumulation. The student should also keep in mind: (1) that associated with carbohydrate utilization are extreme succulence, crispness, and juiciness, properties which are highly desirable in some plants, and (2) that associated with carbohydrate accumulation are non-succulence, woodiness, and resistance to cold and heat, properties which are highly desirable in other plants. Table 5 presents a summary of the relation of the disposition of the carbohydrates to plant behavior, and Figure 16 shows the relation of vegetative vigor and fruitfulness in four tomato plants. Note the three types of behavior.

The Vegetative-Reproductive Balance and Type of Growth. As previously stated, (1) the vegetative phase may be dominant over the reproductive phase, (2) the reproductive phase may be dominant over the vegetative phase, and (3) the vegetative and reproductive phases may not

Table 5

THE VEGETATIVE-REPRODUCTIVE BALANCE

V-R Balance	*Disposition of Carbohydrates*	*Appearance of Plant*
Vegetative processes greater than reproduction processes	Utilization greater than accumulation	Extremely vigorous, vegetative plant. Fruiting suppressed or delayed. Rapid growth of stems and leaves
Reproductive processes greater than vegetative processes	Accumulation greater than utilization	Poorly vigorous, stunted plant. Flowering and fruiting early. Yields low
Vegetative and reproductive processes in equal magnitudes	Accumulation and utilization in equal magnitudes	Moderately vigorous plant Flower and fruiting non suppressed nor delayed. Plant productive

show dominance. Some crops require a dominance of vegetative processes during the entire life cycle, and others require a dominance of vegetative processes during the first part of the life cycle and a balance of vegetative and reproductive processes during the latter part. In general, all plants require a dominance of the vegetative phase during the germination stage. Beyond this stage horticultural crops may be divided into three more or

FIG. 16. Relation of vegetative vigor to fruitfulness in four tomato plants. (Courtesy, Jackson B. Hester, Campbell Soup Company.)

less distinct groups: (1) Herbaceous crops which require a dominance of the vegetative phase during the first stages of growth and a dominance of the reproductive phase during the later stages with the former gradually losing dominance over the latter during the intermediate stage, (2) herbaceous crops which require a lack of dominance of both the vegetative and reproductive phases, and (3) woody plants which require a dominance of the vegetative phase during the first part of each growing season and a dominance of the reproductive phase during the latter part. Examples of each group are presented in Table 6.

Table 6

HORTICULTURAL CROPS CLASSIFIED ACCORDING TO TYPE OF GROWTH

Group	*Crops*
1	cabbage, celery, potato, onion, carnation, chrysanthemum
2	tomato, eggplant, okra, cucumber, sweet pea, *Saintpaulia*
3	apple, peach, citrus, pecan, azalea, crepemyrtle

The Vegetative-Reproductive Balance and the Environment. Since a dominance of the vegetative phase may be desirable in some crops, and a dominance of the reproductive phase may be desirable in others, the question arises, can the vegetative and reproductive phases be controlled by the environment or by cultural methods? As is well known among growers of horticultural crops, certain factors of the environment and certain practices markedly affect the two phases of growth. Principal environmental factors are: (1) The water supply, (2) the temperature, (3) the light supply, and (4) the nutrient supply. Since these factors usually limit the growth and development of plants, they are called the limiting factors in growth and development.

THE LIMITING FACTORS

Meaning of the Limiting Factor. In general, when a process or group of processes is governed by many factors, *the speed of the process is governed by the factor in the minimum or in least abundant supply.* For example, the speed of a railway train is dependent on many factors. Some of these are the condition of the track, the type of engine, the load, and the steam pressure. If the track is in poor condition, it is only through improvement in the track that the increase in speed can be obtained. It would be useless to lighten the load, increase the steam pressure, or change the type of engine.

Similarly, the rate of development of stems and leaves is dependent largely on the amount of sugars made and the amount of nitrate or ammonium nitrogen absorbed and assimilated with the sugars to form proteins. If the supply of available nitrogen in the soil is low, protein formation is accordingly low and the production of leaves and stems is low. In this case the nitrogen supply is the limiting factor, because only through an increase in the available nitrogen supply can an increase be obtained in the growth of stems and leaves. It would be useless to increase the water supply, the light supply, the phosphorus supply, or any other factor except that of nitrogen.

During the winter months light duration and intensity are usually the limiting factors in growth. For example, crops grown in greenhouses produce greater yields in summer than in winter. In winter it would be useless for the grower to increase the temperature, the water supply, or the fertility of the soil. It is only through an increase of the light supply that an increase in growth can be obtained.

In other words, the growth and ultimate yield of any crop is regulated largely by a limiting factor. This does not mean that any one factor remains the limiting factor throughout the entire life of the plant. Sometimes it may be the carbohydrate supply, sometimes the available nitrogen supply, sometimes the water supply, or sometimes the heat supply. Since the limiting factor largely determines the rate of plant growth and development, an appreciation on the part of the student of the importance of the limiting factor is necessary. In many cases the solving of the grower's problems consists in discovering and dealing with the limiting factor. In the discussion of the principal factors limiting plant growth and development in Chapters 3, 4, 5, and 6, it is assumed that *all factors except the one under discussion are in plentiful supply.*

Questions

1. Name the two phases of plant development.
2. Carbohydrates and proteins are used in the making of cells. Explain.
3. Abundant water within the plant is necessary for cell enlargement. Explain.
4. Liberal supplies of energy are necessary for the making and enlargement of cells. Explain.
5. Thickening of the cell walls, and the storage of starch, gums, and mucilages, are manifestations of carbohydrate accumulation. Explain.
6. When a plant should be developing its absorbing roots and leaves and stems, the vegetative phase of growth should be dominant. Explain.

7. Nitrogen deficiency and carbohydrate accumulation frequently go together. Explain.
8. Excessive vegetative growth of young apple trees before they reach their bearing age delays fruitfulness. Explain.
9. Vigorous trees supplied with abundant nitrogen produce fruits which are green longer than those supplied with moderate nitrogen. Explain.
10. In the growing of spinach and leaf lettuce what phase of growth should be dominant? Give your reasons.
11. What balance would you maintain during the flowering and fruiting of tomatoes? Give your reasons.
12. Experiments have shown that the shading of bearing peach and apple trees reduces flower bud formation. Explain.
13. The quality of grape juice and wine varies with the nature of the growing season. Explain.
14. The behavior of green plants is centered around carbohydrate utilization and accumulation. Explain.
15. Stem cuttings stored with large quantities of carbohydrates produce roots at a greater rate than those stored with small quantities of carbohydrates. Explain.
16. Name the principal environmental factors influencing the growth of horticultural plants.
17. What is meant by the limiting factor in growth and development?
18. If air, water, temperature, light, or nutrients become deficient or unfavorable, high yields of high quality crops will not materialize. Explain.
19. What environmental factor is likely to be the limiting factor in the growth of a plant during the summer: (1) at sunrise? (2) at noon? (3) at sunset? Explain.

3

The Water Supply

Assignment 5

Water is one of the essential constituents of living things. Life without water is impossible. Large quantities of water are present in plants. In fact, some students of plant life consider the plant as a supported column of water.

Functions of Water. Water has many important functions in plant life. Water is the solvent and transportation medium for all foods; it combines with carbon dioxide to form sugar in photosynthesis; it combines with starch to form sugars in respiration; and it maintains turgor in all living cells.

To repeat, plants absorb and transpire water. Water is absorbed in the liquid form from the soil in the region of the root hair zone, and water is transpired in the vapor form from any plant surface exposed to the forces of evaporation. For example, roots exposed to the drying effects of air, apples or sweetpotatoes in storage, cut flowers in a room, as well as growing plants, give off water in the form of vapor. *This phenomenon, the giving off of water in vapor form, is called transpiration.*

Plants in full leaf absorb and transpire large quantities of water. For example, a healthy 20-year-old apple tree will give off from 0.50 to 0.75 barrel of water per day and will require from 4500 to 5000 gallons of water per year. Since the leaves of most plants are flattened and broadened and possess stomata for the absorption of carbon dioxide for photosynthesis, a high rate of water loss from these structures is inevitable. This is partic-

ularly true under conditions which promote a high rate of transpiration.

In order that plants can make foods the guard cells must remain turgid to promote the diffusion of carbon dioxide through the stomata. When the guard cells lose their turgor and thus become flaccid, the size of the stomata decreases. This results in a decrease in the rate of diffusion of carbon dioxide into the plant with the resultant decrease in food manufacture and a corresponding decrease in yield. To maintain turgor within the guard cells and other living tissues of the plant the amount of water absorbed per unit of time should equal the amount transpired. However, during the growing period of any particular plant this favorable condition does not always exist. When plants are growing in soil with deficient supplies of water and under conditions of rapid transpiration, the outgo becomes greater than the income, and serious consequences frequently occur. On the other hand, when plants are growing in moist soil and under conditions of low transpiration, the income of water becomes greater than the outgo, and serious consequences occur also. To understand how the water supply influences plant growth and development and how deficits and excesses occur within plants, the student should have a working knowledge of the factors which influence the absorption or the income of water, and of those which influence transpiration or the outgo of water.

ABSORPTION OF WATER

The absorption of water refers to the amount of water going into a plant. Many factors influence the rate of absorption. These factors are divided into: (1) Soil factors and (2) plant factors.

Soil Factors

Principal soil factors are: (1) Amount of available water in the soil, (2) distance through which the available water moves, (3) rate of movement of the available water, and (4) oxygen supply of the soil.

Amount of Available Water in the Soil. The soil is the reservoir for the plant's water. Any particular soil under good drainage conditions will hold, when saturated, a definite amount of water against the force of gravity. This amount of water is called *the field capacity or the moisture equivalent of the soil.* The field capacity is not the same for all soils. The principal factors concerned are: (1) Texture and (2) amount of organic matter. In general, fine textured soils have a higher field capacity than coarse soils, and since the colloids of organic matter have four times the water-

holding capacity of clay and eight times the water-holding capacity of sand, soils high in decomposed organic matter have a greater field capacity than soils low in decomposed organic matter.

Not all of the water held by a soil is available for the plant's use. When the leaves of a plant droop or wilt, the soil contains some water. The water content of the soil at which a plant wilts and does not recover unless water is added is called *the wilting coefficient* or *the wilting percentage of the soil.* Like the field capacity, the wilting percentage varies with the texture and the amount of organic matter. In general, the amount of water at the wilting percentage is higher in fine textured soils than in coarse textured soils, and higher in soils high in organic matter than soils low in organic matter. In fact, very fine textured soils, such as sticky clays, may have a wilting percentage as high as one-half of the field capacity. Thus, from the standpoint of the plant, two types of water exist in the soil: (1) Available and (2) unavailable.

The unavailable water is sometimes called hygroscopic water, and it is firmly held by the soil colloids. The available water is sometimes called capillary water, and it is held by the forces of capillarity. The field capacity is equal to the sum of the unavailable and available water. Table 7 shows the field capacity, the unavailable and the available water in three different soils. Note the greater field capacity of the silt loam than that of the sandy soil, and the greater proportion of available water in the sandy soil than in the silt loam. However, because of the greater field capacity of the loam, it has a greater supply of available water for plants. Figure 17 shows the influence of soil moisture on the growth of young apple trees. Each tree, a representative of an experimental group, from left to right, used 20, 40, 60, 80, and 100 per cent of the available water.

Table 7

Available and Unavailable Water of Certain Soils*

Kind of Topsoil	*Field Capacity (Per Cent)*	*Unavailable (Hygroscopic Water) (Per Cent)*	*Available (Capillary Water) (Per Cent)*
Sandy soil	19.6	3.3	16.3
Silt loam	31.3	10.1	21.2
Black adobe	47.6	12.9	34.7

*From Lyon, T. L., and Buckman, H. O.: "The Nature and Properties of Soils," 3d ed., New York, The Macmillan Co., 1937.

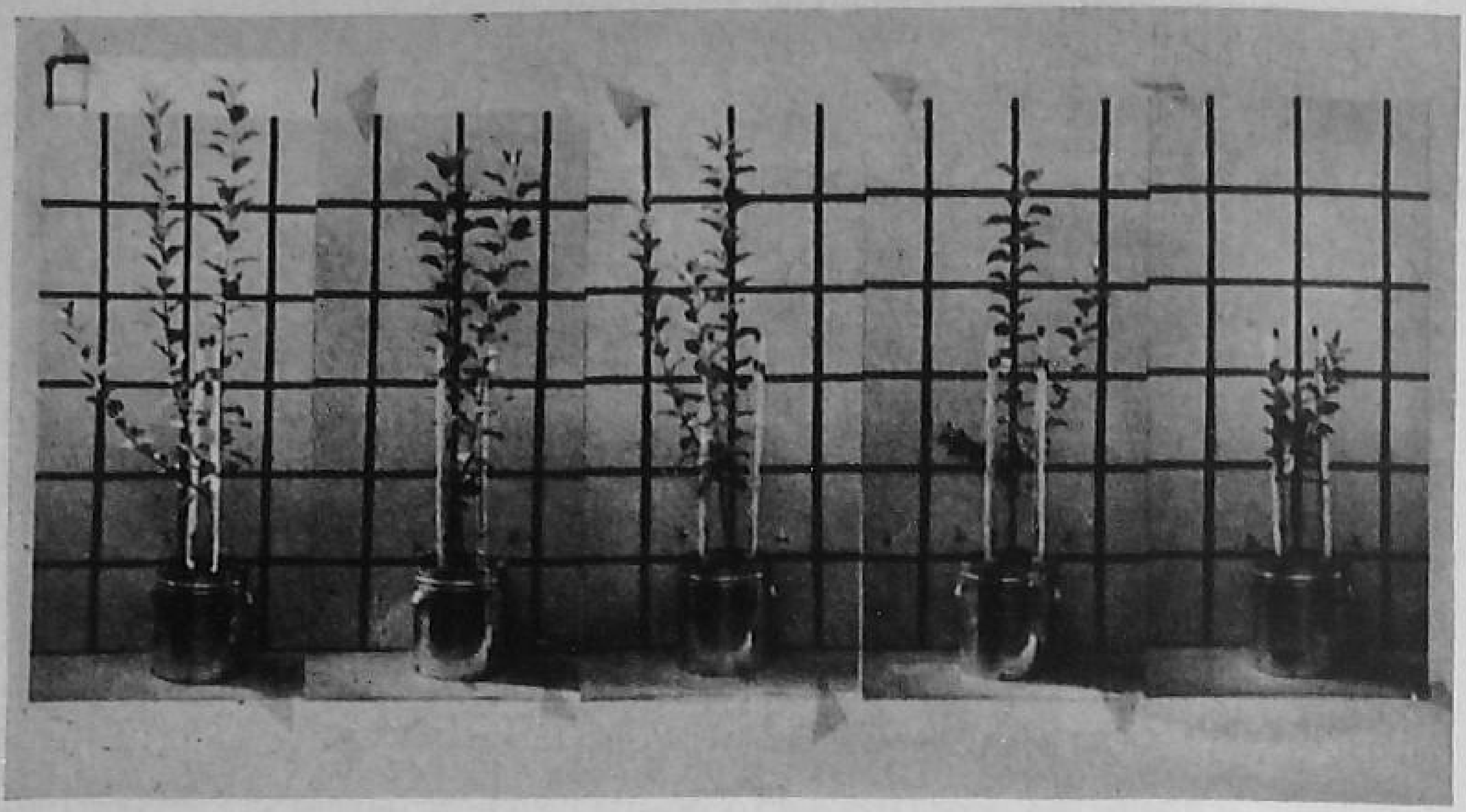

FIG. 17. Relation of the amount of available water to the growth of young apple trees. (Courtesy, A. L. Kenworthy, Michigan State College.)

Distance Through Which Available Water Moves. How far does the available water move? Investigations have shown that the available water moves through the soil for comparatively short distances only—not more than 2 or 3 feet on the average. This short distance through which water moves has an important relation to the depth and density of the absorbing surfaces of root systems and the distance of the water table from the surface of the soil. Since water moves for short distances only, the available water which plants can obtain is limited for the most part to regions of the soil occupied by the plant's roots. In other words, plants with shallow root systems cannot secure water from the lower levels of the soil. Thus, plants with deep or dense root systems are able to withstand droughts to a greater degree than plants with shallow or non-dense systems.

With other factors favorable for root growth, the distance of the water* table from the surface of the soil determines the depth of soil penetration. In general, the roots of most plants which develop extensive root systems penetrate to levels which are 12 to 18 inches from the water table. Within this 12- to 18-inch zone the spaces between the soil particles contain excess water and they lack sufficient oxygen for root development. Thus, a water table close to the surface of the land limits root penetration. Many studies and observations have shown that the height of the water table markedly influences the growth, vigor, and productivity of economic plants. For example, with other factors favorable, the raspberry requires a water table

*In this paragraph, it is assumed that the water table is within a reasonable distance of the soil surface.

from 18 to 36 inches from the surface; the highbush blueberry requires a water table from 12 to 24 inches from the surface; and onions grown on muck require a water level of 24 to 36 inches from the surface. In fact, many growers of onions and celery on muck regulate the height of the water table by means of dams in the drainage ditches. In this way a uniform supply of moisture to the roots is assured.

Rate of Movement of Available Water. The rate at which the available water moves depends on: (1) Soil type, (2) soil temperature, and (3) concentration of the soil solution.

Soil Type. Because of their greater colloidal content, water moves less rapidly in clays than in sands. This relatively slow movement in heavy soils combined with their great field capacity enables plants grown in this type of soil to withstand conditions of drought for a longer period than those grown in sands or sandy loams. In other words, sands must be continually supplied with water either by rain or by irrigation for continued growth and development of plants.

Soil Temperature. Temperature affects the movement of water in two ways. It influences the kinetic energy and viscosity of the molecules. Increases in temperature increase the kinetic energy and decrease the viscosity. Conversely, decreases in temperature decrease the kinetic energy and increase the viscosity. These effects of temperature hold usually between 0° C. and 35° C. Thus, water moves less rapidly in cold soils than in warm soils. This effect of temperature explains, partially at least, why growers use bottom-heated propagation beds in the greenhouse; why they use warm water in the irrigation of warm season crops in the greenhouse in winter; and why evergreen trees may wilt in winter, especially in dry, sunny weather.

Concentration of the Soil Solution. Because water has great solvent properties, the water in the soil contains many substances in solution. The substances in solution, the solutes, naturally get in the way of water molecules and thus retard their movement. Thus, the greater the number of solute particles per unit volume of solution, the greater will be the retardation of movement of the water molecules. Usually, the water of soils contains a low concentration of solutes and the molecules of water move freely from the surface of the soil particles to the root hairs. Sometimes, however, the concentration of the solutes becomes so great that the rate of movement of water is markedly retarded. In fact, the rate of movement may be reversed. Instead of flowing into the plant, water flows out of the plant and into the soil. Sometimes the grower inadvertently causes

this reversal of water movement when he applies large quantities of soluble fertilizer in close proximity to the plant's roots or with the seed.

Oxygen Supply of the Soil. The roots of most economic plants require oxygen for the absorption of water. Experiments have shown that if the oxygen of the soil air is displaced by nitrogen or carbon dioxide, water absorption is reduced or entirely stopped. This need of oxygen for the absorption of water emphasizes the importance of good drainage. If the pore space of the soil is filled with water, oxygen for the absorption of water is absent. In order that excessive water may get away from the soil and that air may get into the soil, drainage is necessary. Most fruit, vegetable, and flower crops require well-drained soils.

Plant Factors

Principal plant factors influencing the absorption of water are: (1) Water-absorbing power of the root hairs and (2) depth and density of the root hair zone.

Water-absorbing Power of the Root Hairs. As previously stated, the water-absorbing region of a plant exists just back of the growing points of the root system. In this region certain epidermal cells elongate, and in this way the area of absorbing surface is considerably increased. These cells are called root hairs. Their function is the absorption of water and nutrients. The water-absorbing power of the root hairs is conditioned by their osmotic pressure and turgor pressure. The osmotic pressure is determined by differences in the concentration of water on each side of the cytoplasmic membrane. This living membrane is semipermeable. It will always allow some substances to pass through it and not allow others. Usually, this membrane is permeable to mineral solutes and water and impermeable to organic substances, such as sugars and proteins in solution. These sugars and proteins are in solution with water within the root hair and usually are in greater concentration than the minerals in solution with water in the soil. Because of the lower concentration of water in the root hairs, water diffuses from the soil into the root. The lesser concentration of water in the root hairs is due largely to their sugar content. Photosynthesis makes the sugars. Consequently, plants with a high rate of photosynthesis and with rapidly developing root systems can absorb more water per unit time than plants with a low rate of photosynthesis and with slowly developing root systems.

Depth and Density of the Absorbing Surface. The depth of the absorbing surface refers to the depth of soil penetrated by the roots. In general,

depth of penetration varies with the kind of plant and the type of soil. Some plants have rather shallow root systems and others have deep root systems. Naturally, a plant with a deep root system can obtain more water than a plant with a shallow root system. This is particularly true during conditions of high transpiration.

Because of differences in percentage of oxygen in various soils, the same kind of plant growing in clay loam will have a more shallow root system than one growing in sand or sandy loam. In fact, in very sandy soils the roots of many crop plants penetrate to the 20- to 25-foot levels and in clay soils they penetrate to the 3- to 4-foot levels.

The density of the absorbing surface refers to the number of root hairs and fine roots which occupy each unit volume of soil. Take two plants, A and B. The root system of plant A has one million root hairs for every cubic foot of soil of a depth, width, and length of 10 feet, and the roots of plant B have only 10,000 root hairs for every cubic foot of soil occupied by the roots. Since water moves for short distances only and because of the greater root density of plant A, it will obtain greater quantities of water than plant B. Thus, both depth of root penetration and degree of root ramification are important, particularly during periods of high transpiration. A prime characteristic of drought-resistant plants is that they develop deep and extensive root systems.

Questions

1. Enumerate the functions of water in plant growth.
2. Define: water absorption; transpiration.
3. Distinguish between: field capacity, wilting percentage, and available water.
4. What is the relation of texture to the field capacity of soil?
5. Roots do not search for water. Explain.
6. Plants obtain their water from that portion of the soil occupied by the roots. Explain.
7. State a disadvantage of: sands; clays.
8. In general, loams are most satisfactory for the growing of most economic crops under non-irrigation. Explain.
9. A plant with a deep root system will withstand drought to a better extent than a plant with a shallow root system. Explain.
10. Greenhouse growers frequently water their seedlings during the winter with warm water. Explain.
11. Growers sometimes withdraw water from their growing crops. Explain how they do this.

12. A high rate of photosynthesis, a high rate of transpiration, and a high rate of water absorption go hand in hand. Explain.
13. In general, farmers should consider the water content, aeration, and fertility of the subsoil. Explain.
14. How does the breaking up of tight subsoils increase crop yields?

Assignment 6

TRANSPIRATION

The outgo of water from plant surfaces in vapor form is called transpiration. Numerous factors influence this process. For convenience they are classified as: (1) Environmental factors and (2) plant factors.

Environmental Factors

Principal environmental factors are: (1) Light, (2) relative humidity, (3) air temperature, and (4) air movement.

Light. Of the total amount of light energy that impinges on chlorophyll-containing tissue, about 10 per cent is reflected, 10 per cent is transmitted, and 80 per cent is absorbed. Not all of the absorbed energy is used in photosynthesis. The part which is not used is changed to heat energy and this, in turn, is dissipated by radiation and by transpiration. Radiation is the transfer of radiant energy through space from a relatively hot body to a relatively cold one. In this way, light is transferred from the sun to the earth. In like manner, the leaves and green stems when exposed to light lose some of the absorbed energy to the environment.

On the other hand, transpiration involves the changing of liquid water to the vapor form. Energy is required to effect this change. Thus, with other factors favorable, the rate of change of liquid water to vapor water will vary directly with the amount of light available. In other words, the greater the light supply, the greater will be the amount of energy absorbed and the greater will be the transpiration rate. Conversely, the lesser the light supply, the lesser will be the amount of energy absorbed and the lesser will be the transpiration rate. Therefore, the transpiration rate will be greater in summer than in winter, and within the same season the rate will be greater on sunny days than on cloudy days or at night.

Relative Humidity. The atmosphere possesses the ability to hold water. When a relatively large amount of water vapor is in the air it is moist. Conversely, when a relatively small amount of water vapor is in the air it is dry. This ability of the air to hold water varies directly with temperature. Thus, the higher the temperature the greater is the ability of the air to hold water.

The amount of water vapor in the air compared to the amount when the air is saturated for any particular temperature is known as relative humidity. When the relative humidity is high, the number of vapor molecules per unit volume of air is high. On the other hand, when the relative humidity is low, the number of water vapor molecules per unit volume of air is also low. In general, since the cells of the spongy tissue are surrounded by films of water, a high relative humidity exists in the chamber of each stomate. Thus, when the stomata are open water will diffuse from the stomatal chambers to the outside air, and the rate of diffusion will depend on the difference in relative humidity of the stomatal chambers on the one hand and in relative humidity of the outside air on the other. In other words, if the outside air contains a small number of water molecules per unit volume, the vapor molecules will diffuse from the region of the stomata to the outside air at a rapid rate. Conversely, if the outside air contains a large number of molecules of water vapor, the rate of diffusion will be at a slow rate. Therefore, the rate of transpiration varies inversely with the relative humidity.

Air Temperature. Since temperature governs the speed of molecules, it governs the rate of diffusion of water vapor from transpiring surfaces to the outside air. Thus, a rise in temperature will increase the speed of the molecules of water vapor and accordingly increase the rate of transpiration. Conversely, a drop in temperature will decrease the speed of the molecules of water vapor, and correspondingly decrease the rate of transpiration. Therefore, with constant light intensity and constant relative humidity and in still air the rate of transpiration will be governed by the temperature.

Air Movement. When air movement is rapid the molecules of water vapor immediately above the transpiring surface are rapidly carried away and the rate of diffusion is accordingly increased. Conversely, when air movement is slow the molecules are displaced less rapidly and the rate of transpiration is relatively slow. Thus, with other factors constant, the rate of outgo of water will be governed by the wind velocity. Therefore, transpiration will be more rapid on windy days than on calm days.

Plant Factors

Principal plant factors influencing transpiration are: (1) Area of transpiring surface, (2) behavior of the guard cells, and (3) water-holding capacity of the plant's tissue.

Area of Transpiring Surface. Since transpiration is the evaporation of water from plant surfaces, plants with a relatively large surface exposed to the air transpire more water than those with a small surface. In fact, with other factors equal, the amount of water transpired is directly proportional to the area of transpiring surface. Thus, plants with a large leaf area* transpire more water than plants with a small leaf area. Similarly, plants without leaves transpire less than plants with leaves. In fact, the loss of water from leafless plants, as in winter, is very low compared to the loss when they are in full leaf. An important practical application is the transplanting of deciduous fruit trees and ornamentals. The removal of trees destroys practically all of the younger part of the root system. A new absorbing system must be formed before absorption can supply the demands of transpiration. This explains why young deciduous fruit trees are set during the non-growing season. During this period the young trees are not in full leaf and the amount of water lost is relatively small.

Behavior of the Guard Cells. In former times plant scientists believed that the guard cells regulated transpiration most of the time. Investigations have shown that this is not the case. In general, when plants are well supplied with water, guard cells influence transpiration only when the stomata are less than one-half open. When the pores are one-half open or more the external factors govern the transpiration rate. Thus, the guard cells may be expected to govern the rate of transpiration from sunset to sunrise, and, for the most part, the external factors may be expected to govern the rate of transpiration from sunrise to sunset.

Water-holding Power of the Tissues. The tissues of plants contain colloids. Some of these colloids possess a great attraction for water. Because of this attraction for water, they are called *hydrophylic colloids.* (The term hydrophylic means water-loving.) The water which is held by these hydrophylic colloids is called bound water. Bound water possesses different properties than free water. It freezes at temperatures lower than 0° C. and evaporates at temperatures higher than 100° C. The molecules of bound water are absorbed on the surface of the hydrophylic colloids and are closer together than those of free water. Thus, bound water is more like a solid

*In general, leaf area=mean area of leaves×number of leaves.

than a liquid. Hydrophylic colloids which bind water are certain gums, mucilages, pentosans, and proteins. This ability to bind water enables many plants to withstand conditions of drought and very low temperatures. For example, well-hardened cabbage and spinach plants contain large quantities of hydrophylic colloids. In this condition they can withstand temperatures as low as 20° F.

THE PLANT AS A WHOLE

The student should remember that all of the factors which influence the absorption of water and transpiration operate together. A warm moist soil thoroughly ramified by the plant's roots combine to promote the absorption of large quantities of water. Conversely, a cold or dry soil limits water absorption. Similarly, high light intensity, low relative humidity, high temperature and high wind velocity combine to promote the high rate of transpiration. Conversely, low light intensity or high relative humidity or comparatively low temperatures or still air limit the transpiration rate.

THE WATER SUPPLY AND THE VEGETATIVE-REPRODUCTIVE BALANCE

The student should bear in mind in this discussion that all factors are favorable for growth other than the water supply. In other words, the water supply is the limiting factor. As previously stated, water is necessary for cell division and cell enlargement. Thus, if abundant supplies of water are available and the plant is subjected to temperatures within the upper half of its optimum range, and is supplied with all necessary nutrients in favorable concentration, and is making large quantities of carbohydrates and proteins, the rate of cell division and enlargement will be rapid. As a result, the sugars and proteins will be rapidly utilized for the making of new cells and the plant will be vigorously vegetative. If moderate supplies of water are available and other factors are in favorable supply, the rate of cell division will be less rapid and the sugars and proteins will be used, not only for the development of stems and leaves but also for the development of flowers and fruit or storage structures. Under these conditions the plant is likely to be moderately vegetative, and will come into bearing at an earlier date than a plant receiving abundant supplies of water. On the other hand, if scant supplies of water are available and with other factors in favorable supply, the rate of cell division will be slow, the growth of

stems and leaves will be accordingly slow and sugars and starch within the plant will accumulate. Because such a plant will develop few leaves and stems, its flower and fruit production will be low. Thus, the water supply may regulate the growth and development of plants to a marked degree. Growers of greenhouse crops and of outdoor crops under irrigation frequently regulate plant growth by manipulating the water supply. These crops are usually grown within their optimum temperatures, in favorable light, and in soils adequately supplied with nutrients. In other words, under these conditions the grower is in a position to regulate the behavior of his crops through the intelligent application of water. The proper application of water is largely responsible for the high yields secured in greenhouses and in the irrigated sections in the West. For the same reason irrigated crops in the East usually produce higher yields than non-irrigated crops.

DEFICITS AND EXCESSES

For continuous growth and development the amount of water going into a plant should, in general, equal the amount going out. If the environment induces a high transpiration rate by high temperature, high light intensity, high wind velocity, or dry air, the area of absorbing surface (the number of root hairs), the supply of available moisture, and the absorbing power of the root hair zone should be correspondingly high. Conversely, if the environment induces a low transpiration rate, relatively low supplies of water or a lesser absorbing surface or a lower water-absorbing capacity are necessary. Under this condition plants may function properly even though the water supply in the soil is comparatively low. However, plants do not always receive adequate supplies of water. Sometimes deficits occur; at other times excesses take place. These unfortunate conditions lower the marketable yield. How do deficits and excesses lower the marketable yield?

Deficits (Outgo Greater than Income). In general, the immediate effect of a water deficit within the plant is a reduction in carbon dioxide assimilation. This reduction in photosynthesis and the amount of foods made correspondingly reduces growth and yield. Recent investigations have shown that the stomata of many crops—apples, pears, peaches, plums, pecans, and lima beans—are markedly sensitive to water deficits. As soon as a water deficit occurs within the plant, the guard cells decrease in size and the stomata begin to close. When the rate of transpiration is high and the rate of absorption of water is low, the stomata begin to close in the early

afternoon. Under extreme conditions they close in the morning and remain closed for the remainder of the day. This closing of the stomata has serious consequences. The rate of diffusion of carbon dioxide is decreased, which results in a decrease in photosynthesis, sugar manufacture, growth, and yield. Growers, particularly in non-irrigated regions, know that yields are low after periods of drought. Note the wilted corn plant in Figure 18.

FIG. 18. A wilted corn plant. Note rolling of edges of leaves. Photograph taken during period of drought. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

In addition to a reduction in yield, a water deficiency within the plant makes orchard trees and other woody plants susceptible to winter injury. The hydrophylic colloids which bind water are made from accumulated carbohydrates. Thus, carbohydrate accumulation is necessary for resistance to low temperatures. Since water deficits reduce carbohydrate manufacture, they reduce carbohydrate accumulation and the amount of water-

holding colloids that can be made. Therefore, water deficits during the growing season make woody plants susceptible to winter injury.

The extreme effect of a water deficit results in wilting. When plants are wilted, the stomata are closed, and, as a result, photosynthesis ceases. Since respiration continues the plants begin to decrease in dry weight. With continued wilting the plants continue to starve, which finally results in death. The effect of water deficits is diagrammatically represented as follows:

Decreasing supplies of water	wilting	death →
Decreasing size of stomata Decreasing rate of food manufacture Decreasing growth and yield With overwintered plants, decreasing resistance to winter injury	No food manufacture. Plant living on reserve substances only	

Symptoms of Water Deficiency. Since a water deficit within the plant retards plant growth and development, a knowledge of the symptoms of water deficiency should be helpful in irrigation practices. One of the first symptoms is a reduction in the rate of stem and twig growth accompanied with the development of healthy dark green leaves. This is followed by the development of slender stems or twigs, small flowers, and small, poorly colored fruit. With certain crops—lemons, peaches, and tomatoes—the leaves under conditions of high transpiration actually draw water from the fruit. This causes a marked decrease in volume of the fruit of lemons, and a pathologic condition known as blossom end rot in tomatoes.

How can water deficits be prevented or reduced? Growers avail themselves of various practices depending on the kind of crop and enterprise. Some growers apply irrigation water. This is particularly the case in regions characterized by low rainfall. Others reduce the light intensity. This is particularly the case in cloth house culture. The cloth reduces the light intensity sufficiently to reduce the rate of transpiration, which in turn makes for more vigorous growth. Most growers transplant and cultivate carefully. Since transplanting always reduces the number of root hairs, it always decreases the water supply within the plant and the rate of absorption. Consequently, care in transplanting is always necessary. When growing crops are cultivated, growers practice shallow cultivation to avoid cutting the feeding roots which are just beneath the surface. These practices—transplanting, cultivating, and irrigating—are discussed more fully in Chapter 12.

Excesses (Outgo Less than Income). The immediate effect of an excessive amount of water within the plant is the development of large sized cells which is manifested by a leggy, drawn-out type of growth. As previously stated, the water supply within the plant determines cell size. If, for a given length of time, the income of water is greater than the outgo, the water pressure within the plant increases and the cells just back of the

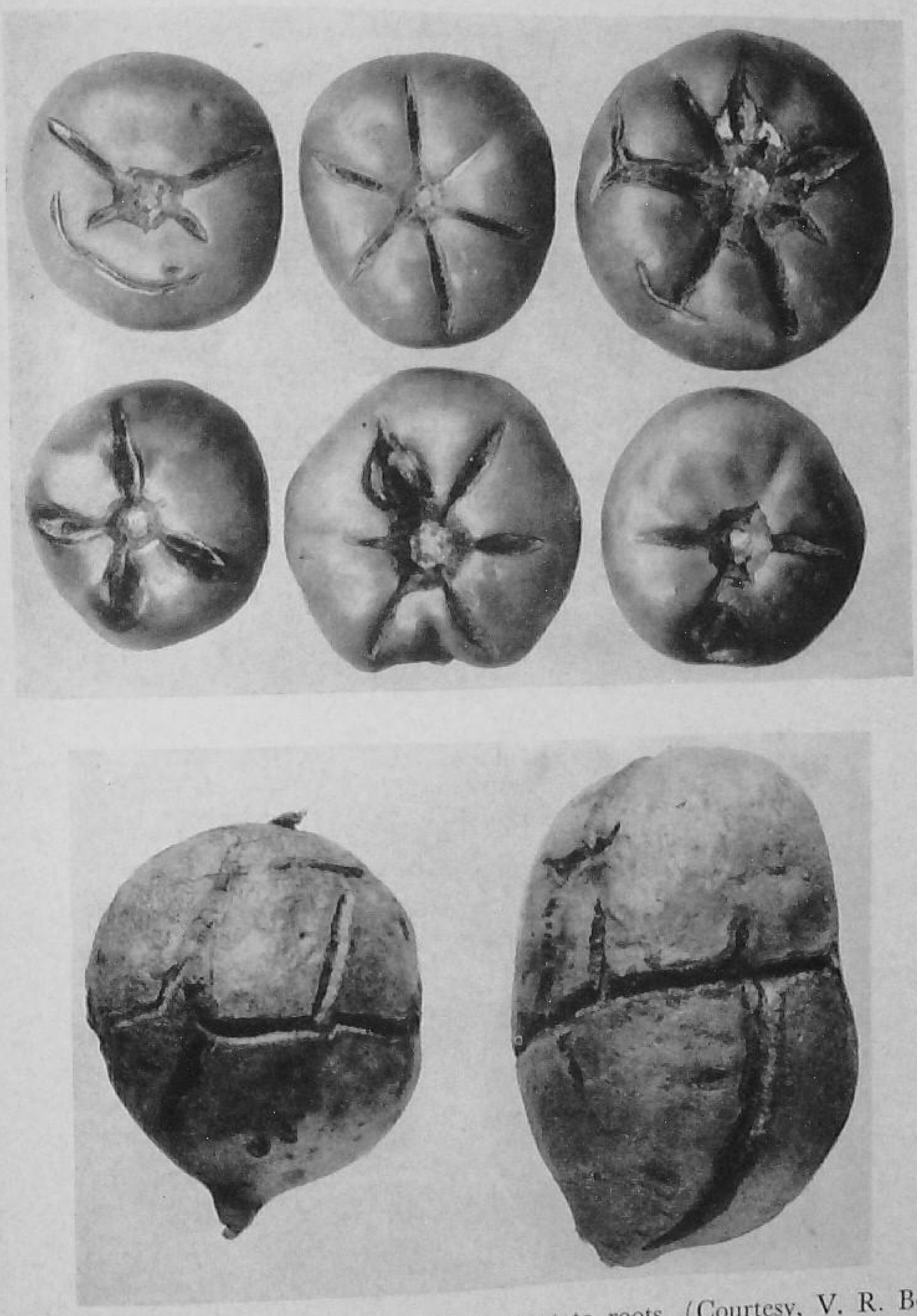

FIG. 19. Cracked tomato fruits and sweetpotato roots. (Courtesy, V. R. Boswell, U.S. Department of Agriculture.)

growing points are unduly stretched. This stretching takes place when the plants are growing close together in warm moist soil. The warm moist soil and the well-developed root system combine to make for an abundant rate of absorption. The close planting reduces light intensity and wind velocity which combine to reduce the rate of transpiration.

With increasing supplies of water within the plant, growth cracks occur. The cell walls break since they cannot withstand the increase in pressure. Horticultural plant products raised on fairly heavy soils frequently crack during wet weather. Examples are cabbage heads, tomato fruits, onion bulbs, carrots, beets, and sweetpotatoes. The wet weather provides abundant soil water. This combined with an extensive root promotes a high rate of absorption. The wet weather also, with its comparatively low temperature, low light intensity, and high relative humidity, makes for a low rate of transpiration. Thus, the high absorption on the one hand and the low transpiration on the other induces the growth cracks. Figure 19 shows cracked tomatoes and sweetpotatoes. The effect of excess water within the plant is diagrammatically represented as follows:

Increasing supplies of water →

Increasing cell size
Long internodes and leggy growth
Bursting cells
Growth cracks

Questions

1. Define transpiration.
2. With constant light intensity and constant temperature and in still air, the rate of transpiration varies inversely with the relative humidity. Explain.
3. Growers of greenhouse crops usually water down the walks twice or three times daily during the summer. Explain.
4. The rate of transpiration is greater in summer than in winter. Explain.
5. The rate of transpiration is greater during the day than during the night. Explain.
6. Plants grown in greenhouses transpire more water in July and August than in April or October. Explain.
7. Sweetpotato and cotton plants frequently wilt during the middle of the day in July, August, and September. They become turgid at night. Explain.
8. In general, the guard cells govern the rate of transpiration from sun-

set to sunrise, and environmental factors govern the rate of transpiration from sunrise to sunset. Explain.

9. A high rate of photosynthesis, a high rate of water absorption, and a high rate of transpiration go together. Explain.
10. With all other factors in favorable supply, show how the water supply controls the type of growth a plant is making.
11. What is the immediate effect of a water deficit within growing plants?
12. When a plant is wilted it is not making carbohydrates. Explain.
13. Under conditions of drought yields are low. Explain.
14. Show how a severe drought during the latter part of the growing season makes orchard trees susceptible to winter injury.
15. A low water supply during the summer in the apple orchard usually means small apples with a dull finish. Explain.
16. Tomato seedlings in the center of flats in the greenhouse frequently become more "leggy" than those on the outside. Explain.
17. Are the "leggy" seedlings described in question 16 reaching for the light? Explain.
18. Cabbage heads burst open and carrot and sweetpotato roots crack during wet weather, particularly when grown in heavy soils. Explain.
19. The cracking of tomato fruits is severe during a rainy period preceded by drought. Explain.
20. The fruit of pruned and staked tomato plants crack more severely than that of non-pruned, non-staked plants. Explain.
21. Flowers will keep in good condition longer if cut in early morning or late afternoon than if cut during the middle of the day. Explain.
22. How do growers prepare woody plants for the winter?

4

Temperature

Assignment 7

A wide range of temperature exists in the planetary system. The temperature on the surface of the sun varies from 6000° to 11,000° C. and that of space in the far reaches of the Milky Way approaches absolute zero, which is —273° C. Living things cannot withstand these wide extremes. In fact, they can only grow and develop within a narrow range. Temperatures above or below this narrow range inactivate or destroy enzymes which are necessary for the chemical reactions within all living things. In general, this narrow range of temperature which supports plant and animal life is that which exists on the earth's surface. However, the temperature on the earth's surface is not always favorable for plant growth and development. Sometimes the temperature may be too low for sugar manufacture or for cell division; sometimes it may be so high as to induce an excessively rapid rate of transpiration and respiration. For any particular kind of plant the temperature may be favorable at one season of the year and unfavorable at another. In fact, temperatures to which plants are exposed may be classified as follows: (1) The temperature range favorable for growth and development and (2) temperature ranges unfavorable for growth and development.

FAVORABLE EFFECTS

The Favorable or Optimum Temperature Range. The favorable temperature range for the growth and development of any particular plant

is known as the optimum temperature range. Within this range, for any kind of plant, all of the fundamental processes—photosynthesis, respiration, water absorption and transpiration, cell division, cell enlargement, and cell differentiation—are proceeding in such a way throughout the life cycle of the plant to make for the highest marketable yield. In other words, the temperature range is such that the highest marketable yields are secured, whether it be the production of a crop of wheat, corn, cotton, alfalfa, tobacco, apples, peaches, strawberries, lettuce, potatoes, roses, carnations, or chrysanthemums.

The optimum temperature range is not the same for all plants. For example, sugar beets, apples, potatoes, and carnations require a lower temperature range than cotton, oranges, dates, figs, sweetpotatoes, or gardenias. In other words, the optimum temperature range of economic plants varies. Some crops have their highest rate of photosynthesis and make more foods and produce higher yields with a relatively low optimum range, and others have their highest rate of photosynthesis and make more foods and produce higher yields within a relatively high optimum range. On the basis of their optimum temperature requirements, horticultural plants are classified as follows: (1) Crops which require a comparatively low optimum range and (2) crops which require a comparatively high optimum range. In general, the former are called *cool-season crops* and the latter are called *warm-season crops*. Typical examples of cool- and warm-season crops are listed in Table 8.

The Optimum Temperature Range and Phases of Growth. To understand the influence of temperature within the optimum temperature range on growth and development, the range is divided into two parts: (1) The lower and (2) the upper. Investigations have shown that within the optimum range for growth and development *the rate of cell division is directly proportional to the temperature*. Thus, there will be a greater rate of cell division on the upper half of the optimum range than on the lower half. This greater rate of cell division makes for a more rapid development of stems and leaves, and a comparatively greater utilization of carbohydrates. Thus, with other factors in favorable supply, and with a high rate of photosynthesis, the maintenance of temperature within the upper half of the optimum range promotes vigorous vegetative growth, and the maintenance of temperature on the lower half induces less vigorous vegetative growth. In other words, temperatures on the upper half of the optimum range promote a rapid rate of vegetative growth and carbohydrate utilization, and temperatures on the lower half of the optimum

range promote a slow rate of vegetative growth and carbohydrate accumulation. Therefore, the upper half of the optimum range favors vegetative processes, and the lower half of the optimum range favors reproductive processes.

Table 8

CLASSIFICATION OF HORTICULTURAL CROPS BASED ON TEMPERATURE REQUIREMENTS

*A. Crops Thriving Best Within the Cool Temperature Range, 45° to 60° F.**		
Cool-season Crops		
Fruit Crops	*Vegetable Crops*	*Flower and Ornamentals*
apple, pear, cherry, plum, gooseberry, currant, strawberry, Labrusca grape, blackberry, raspberry	asparagus, rhubarb, spinach, lettuce, the cabbages, beet, carrot, pea, potato	carnation, sweet pea, snapdragon, violet, calendula, geranium, gypsophila, daisy, petunia, larkspur, lupine, pansy, marguerite, mignonette, stevia, scabiosa, schizanthus, zinnia, swainsonia
*B. Crops Thriving Best Within the Warm Temperature Range, 60° to 75° F.**		
Warm-season Crops		
peach, apricot, citrus, date, olive, tung, Vinifera grape, Rotundifolia grape, fig, persimmon	sweetpotato, tomato, pepper, eggplant, cucumber, cantaloupe, watermelon, pumpkin, squash, beans, okra	rose, poinsettia, gardenia, euphorbia, lily, hyacinth, amaryllis, orchid

*Night temperatures. The day temperature may be 10° to 20° F. higher.

The marked effect of temperature on the growth and development of horticultural crops is manifested by the care and attention given to the maintenance of temperature in greenhouses. The temperature of greenhouses, particularly of commercial establishments, is always under practical control. In fact, many growers use thermostatically controlled heating systems. In this way heat is supplied to the plants only within certain limits of temperature. In general, when the temperature approaches the lower limit of the optimum range for the growth and development of the crop, a thermostat opens valves which admit steam into heating pipes. Conversely, when the temperature approaches the upper limit of the optimum range, the thermostat closes valves which shut off the steam. Although the grower of outdoor crops cannot control temperature in pre-

cisely the same way as the grower of greenhouse crops, he can utilize favorable temperatures by taking advantage of southeasterly or northeasterly slopes and by using various soil types and elevations. For example, the high elevated areas in southern United States permit the successful production of cool-season crops in the summer. In the mountainous regions of North Carolina, South Carolina, and Georgia satisfactory crops of apples, potatoes, cabbage, and garden peas are produced. Other cases could be cited.

Temperature, in combination with other factors, markedly influences the localization of horticultural crop industries. In general, cool-season crops grow best in regions characterized by relatively cool weather, and warm-season crops thrive best in regions characterized by relatively warm weather. For example, the temperature range of the summer season in Holland, Denmark, and Great Britain is particularly suitable for the growing of asparagus, spinach, lettuce, cabbage, cauliflower, garden peas, and other cool-season crops. In these countries warm-season crops such as oranges, grapefruit, lemons, limes, peaches, apricots, and cantaloupes are raised in glass houses because the heat of summer is insufficient to bring these crops to full maturity. In the United States the cool-season vegetables are grown during the summer in the northern regions of the country and during the fall, winter, and early spring in the southern regions. In general, the apple is confined to the northern regions while citrus fruits, dates, and other warm-season crops are grown in the southern regions.

The influence of temperature within the optimum temperature range is diagrammatically presented as follows:

Increasing rate of cell division →

Slow growth	Moderate growth	Vigorous growth
accumulation of carbohydrates dominant over utilization		utilization of carbohydrates dominant over accumulation

UNFAVORABLE EFFECTS

The unfavorable effects of temperature are classified as follows: (1) Growing season temperatures above the optimum range, (2) growing season temperatures below the optimum range, and (3) unfavorable effects of winter temperature.

Temperatures Above the Optimum Range. Plants subjected to temperatures above their optimum range, particularly during the later stages of growth, generally produce low yields. How are these low yields produced? In general, for any given plant, the yield equals the amount of carbohydrates made minus the amount used. Since carbohydrates are made by the process of photosynthesis and are used by the process of respiration, the yield equals the rate of photosynthesis minus the rate of respiration. Increases in temperature speed up both processes, but *at temperature above the optimum range respiration is speeded up to a greater extent than photosynthesis.* Thus, the higher the temperature above the optimum range, the lesser is the yield. Figure 20 illustrates the relation of the rate of photosynthesis and the rate of respiration to yield. Note that the rate of respiration at point A equals the rate of photosynthesis. The shaded area is the difference between the rate of photosynthesis and the rate of respiration and equals the yield per unit time. In other words, in order that plants may grow and develop, the rate of photosynthesis must always be greater than the rate of respiration. In general, the greater the difference between the rates of these processes, the greater is the yield. This effect of temperature above the optimum range for growth explains why potatoes and other cool-season crops are grown in the South during the spring and fall only; why carnations have weak, spindling stems during the summer; why the stems become thick and plants blossom during the winter in the greenhouse; why garden peas fail to produce high yields during hot weather; why they produce abundant yields during cool weather; why the flowers of *Pimula sinesis*, variety *rubra*, are red at comparatively low temperatures and at high temperatures they are white; why the apple industry, for the most part, is located in the northern regions of the country and in high elevated regions in the upper South; why the Concord grape industry is confined largely to the region of the Great

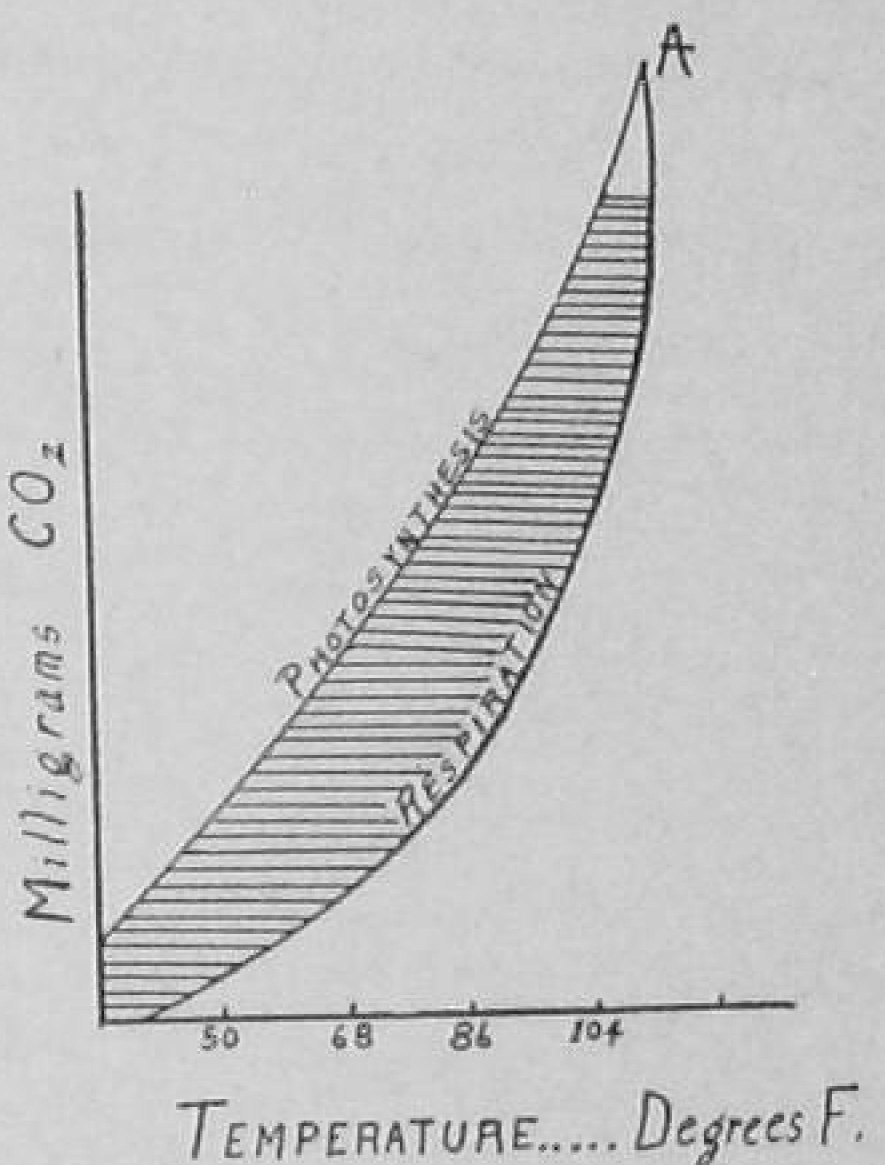

FIG. 20. Relation of photosynthesis and respiration to yield of crops.

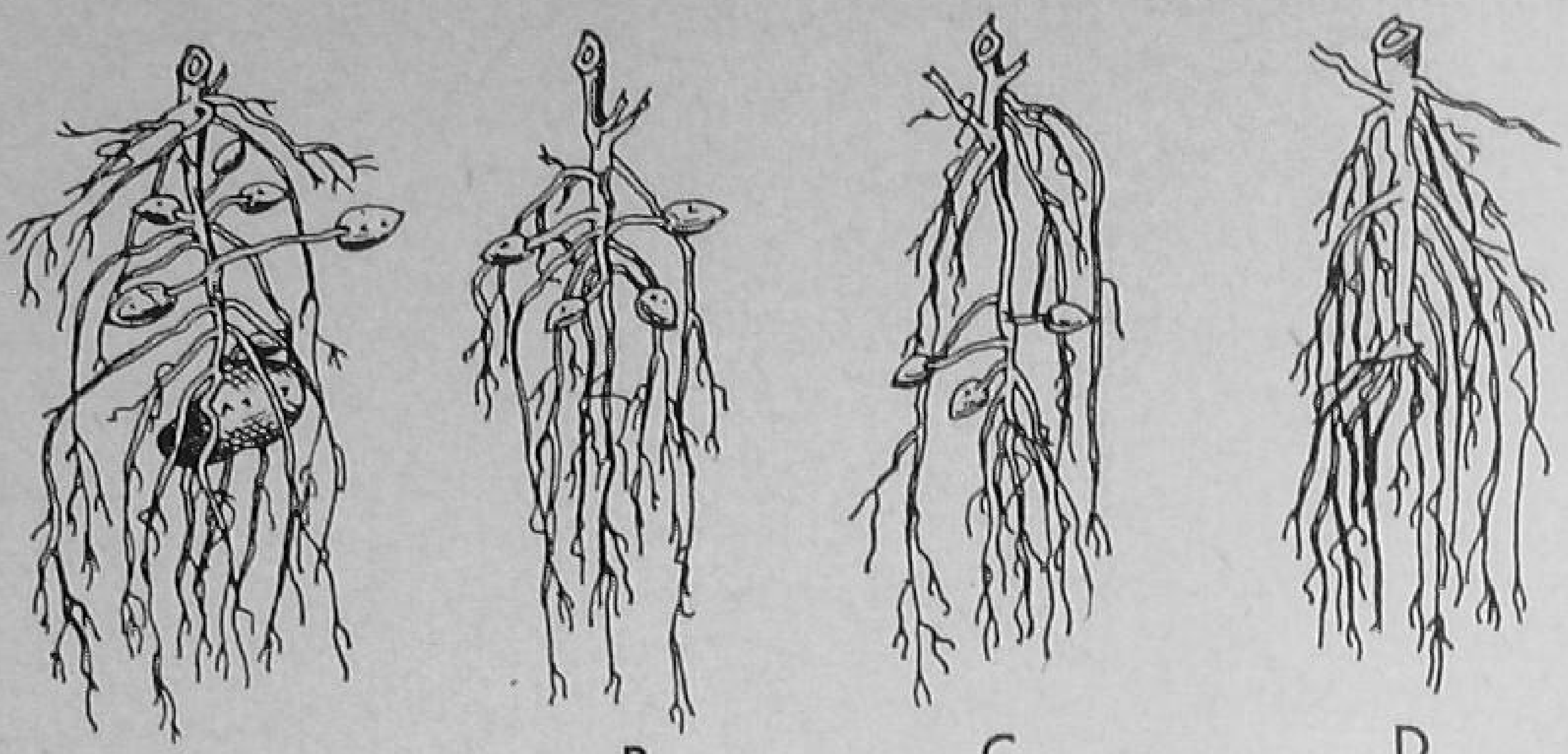

FIG. 21. Effect of temperature on the development of potato tubers. (A) 68° F., 20.9 gm. (B) 73° F., 5.0 gm. (C) 79° F., 1.6 gm. (D) 84° F., 0 gm. (Redrawn from Fig. 9. *Minn. Agr. Exp. Sta. Tech. Bul. 34*, 1925.)

Lakes; and why the cool-season vegetable and flower crops are grown in the winter garden areas in the South and in the summer in the North. Many other examples could be cited. Figure 21 shows the effect of temperature above the optimum range on the development of tubers of the potato. Note that as the soil temperature increased above the optimum range the lesser is the yield of the tubers.

Temperatures Below the Optimum Range. Plants subjected to temperatures below their optimum range for growth also produce low yields. How are these low yields produced? *The rate of photosynthesis and the rate of protein formation are at a minimum.* As a result growth and development are slow; thus, yields, if any, are low. Warm-season crops are more likely to become subjected to temperatures below their optimum range than are cool-season crops. This is particularly true if they are grown in regions characterized by low summer temperatures. This effect of temperature below the optimum range for growth explains why warm-season vegetable crops thrive well only in favorable locations in the coastal regions of Alaska; why the northern limit of the sweetpotato industry extends from New Jersey to southern Ohio, Indiana, and Iowa; why the citrus industry is confined to central Florida, to the coastal belt of Alabama, Mississippi, and Louisiana, to the Rio Grande Valley of Texas, and to southern California; and why the date industry is limited to the Coachella Valley of southern California. Many other examples could be cited.

Temperature also influences the adaptability of varieties within an industry. For example, Winesap and York Imperial apples require a com-

paratively high optimum temperature, and Baldwin and McIntosh a comparatively low optimum temperature. Thus, the Winesap is more adapted to the southern half of the apple belt and the Baldwin is more adapted to the northern half. The Earliana and Bonny Best tomato varieties thrive best in the northern regions, and Marglobe thrives best in the southern regions.

Questions

1. State the general effects of temperature on photosynthesis and respiration.
2. What is meant by the optimum temperature range for plant development?
3. The maintenance of temperature on the upper half of the optimum range favors vegetative processes and the maintenance of temperature on the lower half of the range favors reproductive processes. Explain.
4. In general, temperatures on the lower half of the optimum range are more favorable for the development of large, highly colored flowers than temperatures on the upper side. Explain.
5. During the period of fruit maturation, clear sunny days and cool nights are more favorable for the development of the red pigment on the red varieties of apples than cloudy days and warm nights. Explain.
6. In general, the red varieties of tomatoes develop lycopin (the red pigment of tomatoes) more readily in the North in July, August, and September than in the South during the same months. Explain.
7. At what time of the growing season in the South would you expect tomato fruits to develop their highest color? Explain.
8. How do temperatures above the optimum range for growth produce low yields?
9. Investigations have shown that potatoes produce low yields when the rate of respiration approaches the rate of photosynthesis. Explain.
10. Garden peas planted 3 or 4 weeks before the average date of the last killing frost in the South generally produce greater yields than those planted 2 or 3 weeks later. Explain.
11. The Puget Sound district of the United States is particularly favorable for the growing of garden peas. Explain.
12. Carnations grown in the summer possess thin, spindling, weak stems; those grown in the fall and winter possess thick, stiff, stout stems. Explain.
13. For the growing of greenhouse crops the optimum cloudy day temperature range is not much higher than the optimum night temperature range. Explain.
14. Cool-season vegetable crops are grown in the summer in the North, and in the fall, winter, and early spring in the South. Explain.
15. How do temperatures just below the optimum range for growth produce low yields?

16. In your opinion can satisfactory crops of apples be produced in the South? If so, where? Explain.
17. In the British Isles cucumbers, cantaloupes, and tomatoes are grown more satisfactorily under glass than outdoors. Explain.
18. Sweetpotatoes are grown in regions which have a growing season of at least 150 to 170 days during which the temperature is relatively high. Explain.

Unfavorable Effects of Winter Temperature

Harmful effects of winter temperature are classified as follows: (1) Injuries due to immaturity of the tissues, (2) injuries due to unseasonably low temperatures, (3) injuries due to inability of the trees to withstand winter drought, and (4) injuries due to lack of sufficient cold.

Injuries Due to Immaturity of the Tissues. The ability of woody plants to withstand low winter temperature is dependent on the ability of the tissues to hold water. This in turn is related to the ability of the protoplasm to make a group of compounds known as hydrophylic colloids. These hydrophylic colloids have a large surface in proportion to their size and absorb large quantities of water on their surfaces. This water is called bound water and cannot be frozen at the usual subfreezing temperatures. Investigations have shown that the protoplasm of mature tissue can withhold its water against the force of freezing to a greater extent than that of immature tissue. Since maturity of the tissues is associated with and is dependent on carbohydrate accumulation, the ability of the protoplasm to withstand cold is associated with carbohydrate accumulation. Thus, trees or shrubs in which vegetative processes are dominant over reproductive processes when cold weather ensues, are more predisposed to injury because of immaturity than trees or shrubs in which reproductive processes are dominant. Accordingly, environmental conditions or practices promoting growth and lowering carbohydrate accumulation particularly during the latter part of the growing season will predispose the trees to injury. Therefore, late cultivation, late irrigation, heavy fertilization, and severe pruning should be avoided.

Injury due to immaturity of the tissues may be severe or mild, depending on the degree of carbohydrate accumulation in the trees and the severity of the temperature. Thus, weakly vegetative trees and vigorously vegetative trees are likely to be injured to a greater extent than moderately vigorous trees. Manifestly, the protoplasm of moderately vigorous trees is more resistant to low temperatures than that of weakly vegetative and vigorously vegetative trees. As previously stated, the accumulation of

carbohydrates is associated with resistance to low temperature. Weakly vegetative trees are low in carbohydrates at the beginning of winter because they had a low rate of photosynthesis in the summer and fall, and vigorously vegetative trees are low in carbohydrates because most of the foods had been used for cell division, cell enlargement, and the initial stages of cell differentiation.

A drop in temperature of 30°, 40°, or 50° F. is more severe than a drop of 10°, 15°, or 20° F. For example, on November 11, 1940, the temperature in mid-western United States dropped from approximately 50° to 10° F. within a very short period. The sudden drop in temperature severely injured the wood of many deciduous tree fruits and ornamentals. Severe injury is manifested by killing back of most of the twigs and by killing the conducting and storing tissues—a condition known as Blackheart. Thus, the minimum temperatures and duration of the minimum temperatures in any region determine, to some degree at least, the localization of fruit crop industries. The many horticultural plants vary in their ability to withstand low winter temperatures. Some are resistant while others are not. As previously stated, resistant or hardy plants possess the ability to bind their water while non-resistant non-hardy plants do not possess this ability. Examples of hardy and non-hardy horticultural crops are shown in Table 9, and winter injury to old and young apple branches is shown in Figure 22.

Injuries Due to High Temperatures Followed by Low Temperatures. Unseasonably high temperatures during late winter and early spring fol-

Table 9

Hardy and Non-hardy Horticultural Plants

Fruits	*Vegetables*	*Ornamentals*
	Hardy	
apple, plum, pear, peach, cherry, raspberry, blackberry, blueberry, cranberry, Labrusca grape	the cool-season crops (potato excepted)	flowering peach, quince, hawthorn, rose, spirea, barberry, lilac
	Non-hardy	
citrus, date, olive, fig, Muscadine grape	the warm-season crops	magnolia, nandina, cape jasmine, crepemyrtle, camellia

FIG. 22. Examples of winter injury. (*Left*) Bark on trunk of Golden Delicious apple tree. (*Center*) Freezing cracks on main branch. (*Right*) Freezing cracks on young branches. (Courtesy, A. B. Groves, Virginia Polytechnic Institute.)

lowed by low, usually freezing temperatures, are frequently injurious in orchards of southern United States. The warm period may extend from two to four weeks and the daily temperature may fluctuate from 40° to 75° F. This temperature range is sufficiently high to promote the absorption of water, the swelling of the buds, and the opening of the flowers. What is more important is that the buds lose their hardiness or resistance to low temperature. As a result, the near-freezing or sub-freezing temperatures which follow the warm period kill the buds and blossoms. Thus, for any particular kind of fruit, early blooming varieties are more susceptible to this type of injury than late blooming sorts. Because comparatively lower temperatures exist in the North, the killing of buds and blossoms is less frequent in this region than in the South.

Injury Associated with Winter Drought. The tops of trees and shrubs lose water in the winter. The rate of loss is a function of the evaporating power of the air. Thus, the higher the evaporating power of the air the greater is the rate of transpiration. The water which is lost by the tops must be replaced by the absorption of water through the roots. If the soil is dry, practically very little, if any, water absorption takes place and the tissues gradually become desiccated and finally they die. This type of injury is more evident in the younger portion of the tops than in other parts of trees and shrubs. In the apple, flower buds and one-year-old wood suffer heavily. With extreme conditions the damage extends down-

ward. Conditions which promote excessive drying out of mature tissues are low water intake combined with a high rate of transpiration. Accordingly, winter injury due to drought is more common in regions characterized by light summer rains, a dry atmosphere, and intense winter cold than in regions characterized by moderate rains, a humid atmosphere, and mild cold. How can this type of injury be reduced or avoided? Manifestly, practices which increase the water content of the soil and the water absorption of the tree and which reduce the rate of transpiration would be beneficial. Accordingly, the application of irrigation water, clean cultivation, and the judicious use of windbreaks are helpful.

Injuries Due to Lack of Sufficient Cold. To appreciate the effect of insufficient cold on deciduous plants during the winter, the student should clearly differentiate between the "rest period" and the "dormant period." As an example, let us study the behavior of four comparable lots of two-year-old peach trees. The four lots are of the same age and variety and are grown in tubs in order that they can be moved from place to place. Lot A is grown in a warm greenhouse from October 1 to February 1. Lot B is allowed to remain outdoors from October 1 to November 30 and brought into the greenhouse December 1. Lot C is allowed to remain outdoors from October 1 to December 31 and brought into the greenhouse January 1, and lot D is allowed to remain outdoors from October 1 to February 1. Let us assume that the temperature in the greenhouse is maintained between 50° and 70° F. and that the mean temperature range outdoors varied between 30° and 65° F. from October 1 to November 30; between 20° and 65° F. from October 1 to December 31; and between 15° and 65° F. between October 1 and February 1. Thus, the different temperature treatments are as follows: for lot A a warm temperature throughout the entire period; for lot B a cold temperature for a short period followed by a warm temperature for a long period; for lot C a cold temperature for a long period followed by a warm temperature for a short period; and for lot D a cold temperature throughout the entire period. How would the plants of these lots appear by February 1? Those of lot A would show no signs of flower bud development. Those of lot B would show some signs of bud development but in general growth would be unsatisfactory. Those of lot C would have developed their flower and leaf buds abundantly, and those of lot D would show no signs of bud development. The plants of lot A are *in the rest period*. Those of lot B are *coming out of the rest period*. Those of lot C are *out of the rest period and out of the dormant period*, and those of lot D are *out of the rest period and in the dormant period*,

period. The student will note that the trees of lot A were given a favorable temperature for growth and the buds failed to grow. Evidently, conditions within the trees were unfavorable for the growth of the buds. Note also the differences in behavior between lots C and D. Obviously, these differences are due to the differences in temperature given the two lots. Conditions within the trees of lot D were favorable for the development of the buds but external conditions were unfavorable. Thus, the rest period is induced by a set of conditions within the tree which is unfavorable for growth processes. *The internal conditions are unfavorable.* Similarly, the dormant period is induced by unfavorable environmental conditions while the internal conditions are favorable. Therefore, the rest period and dormant period have distinct meanings. *During the rest period the internal conditions are unfavorable for the growth of the buds.* The environment may or may not be favorable. *During the dormant period the internal conditions are favorable but the external or environmental conditions are unfavorable for the growth of buds.*

The stems of certain plants have a rest period. In temperate regions this rest period usually begins at the end of the growing season and ends sometime during the winter or early spring. The length of the rest period depends on the species. For example, oaks have a longer rest period than apples and apples have a longer rest period than peaches.

A certain amount of cold is necessary to bring the tops of woody plants out of the rest period. For example, investigations have shown that commercial varieties of peaches require a total of 800 to 1000 hours below 45° F. to bring them out of the rest period. In certain districts—the southern half of Alabama, Georgia and Mississippi, and in southern California—the amount of cold necessary to break the rest period of peaches does not always occur. In fact, the lack of sufficient chilling weather to break the rest period of buds of peaches is responsible for establishing the southern geographical limit for the successful production of the peach crop in the United States. This lack of sufficient cold is naturally of greater concern to the grower in the southern limits of peach culture than to the grower in other regions. In northern regions the temperatures are sufficiently low to break the rest period, and in the extreme southern regions they are frequently too mild. At present scientists are endeavoring to develop commercial types of peaches with short rest periods. In this way, the southern geographical limit of commercial peach production may be extended. Figure 23 shows two Elberta peach trees in the spring of 1949. The tree on the left was part of an orchard near

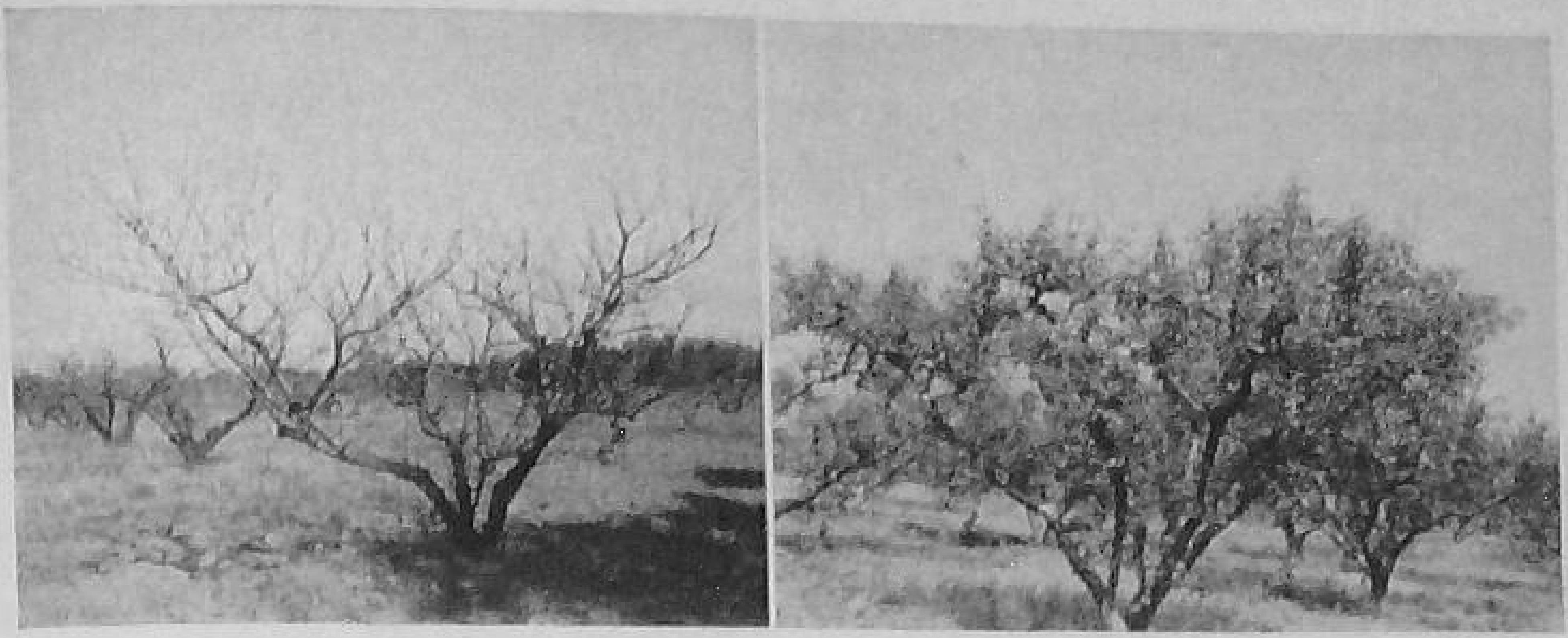

FIG. 23. Appearance of two peach trees in the spring of 1949 in southeastern United States. The tree on the left is still in the rest period, while the tree on the right is growing vigorously. Each tree was photographed within four days of each other. (Courtesy, J. H. Weinberger, U.S. Department of Agriculture.)

Albany, Georgia, and was photographed on April 19; and the tree on the right was part of an orchard near Jonesboro, Georgia, and was photographed on April 15. The winter season of 1948–1949 in the Southeast was unusually mild.

A certain amount of cold is also necessary for the growing of certain herbaceous crops. For example, rhubarb forcers allow the fleshy rhizomes to remain in the soil for a period of three to four weeks during the first part of the winter before removing them to the forcing structures. During this period the crowns receive sufficient cold to break the rest period. Thus, a period of chilling temperatures is necessary for the rapid production of the rhubarb petioles. The florist who forces lily bulbs frequently treats the storage structures with hot water.

SPECIFIC TEMPERATURE EFFECTS

Temperature and Starch-Sugar Transformations of Harvest Products. The quality of many horticultural products is determined by the degree of sweetness. In crops where the principal reserve carbohydrate is starch the following reactions are involved:

(enzymes)

(1) sugar $\longrightarrow$ starch
(2) starch $\longrightarrow$ sugar
(3) sugar $\longrightarrow$ $CO_2 + H_2O +$ heat and other forms of energy

Low temperature decreases the rate of all three reactions. But the rate of decrease is not uniformly the same. Investigations have shown that re-

actions (1) and (3) are decreased more than (2). In this way sugars in the plant product accumulate and remain at a high level. High temperatures increase the rate of all three reactions, but (3) increases more than (1) or (2). Therefore, the sugars remain at a low level. In many cases they become depleted. The effect of high and low temperature on sugar content is illustrated in Table 10. Note that the low temperature actually

Table 10

STARCH-SUGAR TRANSFORMATION IN HARVESTED PRODUCTS

Disposition of Sugar in Plant Product	*Temperature*	
	High 55°–65° F.	*Low* 35°–45° F.
Units of sugar available	10.0	10.0
Units of sugar lost in reaction (1)	5.0	2.5
Units of sugar gained in reaction (2)	1.0	0.8
Units of sugar left	6.0	8.3
Units of sugar lost in reaction (3)	4.0	2.0
Units of sugar left	2.0	6.3

conserves the sugars. This effect of temperature on starch-sugar transformation of certain harvested products explains why potato tubers become sweet when stored at temperatures of 32° to 40° F.; why sweetpotato roots stored at 55° F. are more sweet than those stored at 60° F.; why sweet corn raised in Maine remains sweet for a relatively long time; why garden peas are the sweetest if cooked immediately after they are harvested; why apples contain more sugar when stored at 40° F. than at 55° F.; why sugar flows in the hard maple in the spring; why sugar cane becomes sweet after the first frost.

Temperature and Diseases. As with horticultural crops, many plant pathogens—fungi and bacteria which cause disease—have optimum temperatures for growth. In general, these organisms may be placed in either of two groups: (1) Those which thrive best in cool weather and (2) those which thrive best in warm weather. Examples of cool-weather pathogens are the fungi which cause apple scab and peach leaf curl. Examples of warm-weather pathogens are fungi which cause bitter rot and black rot of apple, smut on corn, and fusarium wilt on tomato. These differences

in temperature requirements explain why a certain disease is prevalent in one region of the country and non-existent or of little consequence in another. For example, peach leaf curl is more prevalent in northern peach-growing districts. In fact, this disease does not exist in central Georgia, central South Carolina, and central Mississippi. On the other hand, black rot and bitter rot of apples are more prevalent in southern apple-growing districts because of the higher temperature requirements of the organisms responsible for these diseases. Many other examples could be cited.

Insect pests are also influenced by temperatures. In general, there are more generations in the South than in the North simply because of the longer period of favorable temperature for reproduction. For example, the codling moth caterpillar, a serious insect pest of the apple, has only one generation in Maine, three or four in New Jersey, and seven or eight in western South Carolina; the cucumber beetle has two or three generations in Michigan and four or five in south Mississippi. In addition, the cold winter temperatures of the North destroy many insect pests. The mild winter temperatures of the South favor their hibernation.

Questions

1. Fruit trees and other woody plants low in vigor are more susceptible to winter injury than trees moderate in vigor. Explain.
2. Fruit trees and other woody plants with heavy crops are more likely to be injured by low temperatures during the following winter than trees with moderate crops. Explain.
3. Partial defoliation, particularly during the latter stages of growth, makes woody plants susceptible to winter injury. Explain.
4. In general, the Great Plains region is unfavorable for the development of satisfactory crops of the deciduous fruits. Explain.
5. In northern United States peach trees often have the past season's growth injured during the winter and in southern United States the flower buds are often the only part of the tree injured. Explain.
6. A warm November and December and a cold January and February in the southern United States are usually followed by good crops of apples and peaches. Opposite conditions often result in smaller crops. Explain.
7. What is meant by: the "rest period"? the "dormant period"?
8. Under the usual conditions prevailing in a greenhouse, a peach, an apple tree, or a grapevine which has grown there for one season would not come out of its rest period in March or April (the usual time) but in early summer. Explain.
9. Explain why commercial apple and peach orchards do not exist along the Gulf Coast or in Florida.

10. Explain why citrus orchards do not exist in the northern regions.
11. Garden peas become hard, yellow, and unpalatable if after picking they are exposed to relatively high temperatures. Explain.
12. Peas stay comparatively sweet when kept cool. Explain.
13. Garden peas transported long distances in warm weather are shipped with crushed ice in the center of the basket. Explain.
14. Peas canned immediately after they are picked contain more sugar than those canned two hours after picking. Explain.
15. Harvested sweet corn ceases to remain sweet if subjected to high temperatures. Explain.
16. How would you expect high temperatures to affect quality and length of the harvest period in sweet corn?
17. Experiments have shown that sweet corn stored at 86° F. loses its sweetness six times faster than that stored at 32° F. Explain.
18. One ton of husked green corn during the first 24 hours of storage at 30° C. loses about 3 pounds of sugar. Explain. Can the loss of sugar be entirely prevented? Can it be retarded? If so, how?
19. Parsnips subjected to chilling temperatures become sweet. Explain.
20. Spinach canned in the fall is sweeter than that canned in the spring. Explain.
21. Heating garden peas for five minutes to 180° F. and immediately placing them in cold storage at 32° F. resulted in little or no loss of sugars. Explain.
22. Certain diseases and insects are more prevalent in some regions than in others. Explain.

5

Light

Assignment 8

Light is a form of radiant energy. It travels from the sun to the earth in discrete units or parcels called *quanta* or *photons.* Light of long wave length comes in small parcels, and light of short wave length comes in large parcels. Each parcel contains a definite amount of energy which is inversely proportional to the wave length. Thus, the quanta of short wave length contain more energy than the quanta of long wave length.

Light has weight. About one ten-thousandth of an ounce of light falls every minute on each square mile of the earth's surface. It travels at an average rate of 186,000 miles per second and exerts a pressure of 0.000,000,000,04 atmosphere.* Scientists have estimated that the weight of light emitted from the sun is about 250 million tons per minute.

Light has marked effects on the growth and development of plants. To obtain a working knowledge of these effects, a study of the components of light is necessary. These components are: (1) Intensity, (2) quality, and (3) duration.

Light Intensity. Light intensity refers to the concentration of light waves. It is the number of light waves or quanta impinging on a given area. Light intensity varies with the day, with the seasons, and with the distance from the equator. It gradually increases from sunrise to the middle of the day and gradually decreases from the middle of the day to sunset; it is high in summer, moderately high in spring and fall, and low in winter;

*An atmosphere exerts a pressure of 15 pounds per square inch.

and it is highest at the equator and gradually decreases from the equator to the poles. Thus, for any season light intensity is less in northern United States than in southern United States. Other variations in light intensity are due to dust particles and water vapor in the atmosphere, to differences in slope of the land, and to differences in elevation.

How does light intensity influence the growth and development of plants? Its influence is due largely to its effects on photosynthesis. How does light intensity influence photosynthesis? As previously stated, light energy is necessary for the union of carbon dioxide and water in the formation of carbohydrates. Thus, *the primary function of light in the photosynthetic reaction is to furnish the energy for the union of carbon dioxide and water.* Since energy is necessary for the union of carbon dioxide and water in the formation of carbohydrates, and since this energy comes from the sun, the greater the amount of energy available, with other conditions favorable, the greater will be the rate of photosynthesis. In other words, with other factors in abundant supply, increases in light intensity make for increases in the rate of photosynthesis. Numerous investigations have shown that within limits this is the case. Three examples are cited: Investigations at the Michigan Experiment Station with the Grand Rapids Forcing tomato, a variety adapted to greenhouse culture, showed that the percentage of fresh weight, dry weight, manufactured foods, and yield correlated rather closely with light intensity. The plants were grown in a greenhouse from February 15 to June 15 and at the beginning of the test they were divided into three groups. One group was

Table 11

EFFECT OF LIGHT INTENSITY ON THE GROWTH OF TOMATOES

Treatment	*Relative Amount of Light Admitted*	*Average Daily Intensity (Foot-candles)*	*Yield (Pounds of Fruits)*	*Relative Chlorophyll Content*	*Relative Efficiency*
Plants in full sunlight	100	1140	65	High	High
Plants under one layer of cheesecloth .	50	583	51	Moderately high	Moderately high
Plants under two layers of cheesecloth .	25	261	32	Low	Low

grown in full sunlight, one other under one layer of cheesecloth, and the third under two layers of cheesecloth. The one layer of cheesecloth admitted 50.4 per cent of the light, and the two layers admitted 25.0 per cent of the light. Certain results are presented in Table 11. Note that the plants grown in full sunlight had a greater chlorophyll content and a greater yield than those grown under one layer of cheesecloth and the plants under one layer of cheesecloth had, in turn, a greater chlorophyll content and produced a greater yield than those grown under two layers. Thus, the plants grown in full sunlight had the highest rate of photosynthesis followed by plants grown under one layer of cheesecloth and under two layers in the order named. Figure 24 shows the relative thickness and

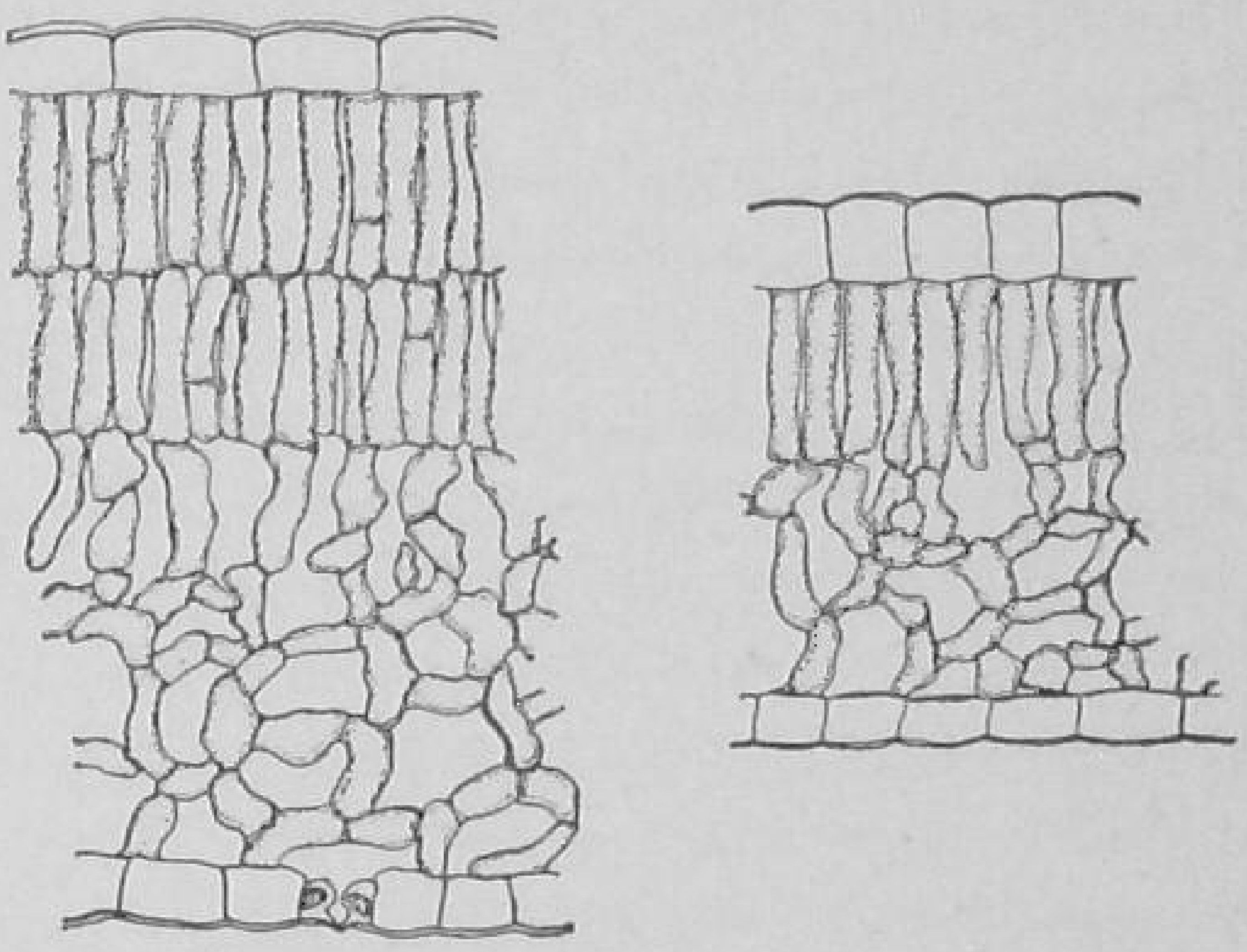

FIG. 24. Sun and shade leaves of apple. (*Left*) Sun leaf. (*Right*) Shade leaf. (Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

number of rows of palisade cells of the leaves of unshaded and shaded apple trees. Note the greater thickness of the leaves grown in sun.

Results of a study of the daily rate of photosynthesis of an eight-year-old McIntosh apple tree at Cornell University showed that for the entire tree the rate of photosynthesis increased with increases in the light intensity up to full sunlight. For example, the average rate of carbon dioxide assimilation on five cloudy days was 5.2 mg. per hour per 100 square centimeters of leaf surface, and the average rate of photosynthesis on five clear sunny days was 20.6 mg. During the middle part of a clear day there was more light than the leaves needed. However, on cloudy days there was insufficient light to carry on a high rate of photosynthesis.

Similar results were secured at the Ohio Experiment Station with the

Better Times greenhouse rose. At light intensities varying from 2300 to 3100 foot-candles, the rate of photosynthesis varied from 10.5 to 11.8 mg. of carbon dioxide per hour per 100 square centimeters of leaf surface. At lower light intensities, varying from 800 to 1200 foot-candles, the rate of carbon dioxide assimilation varied from 4.0 to 8.5 mg. per hour per 100 square centimeters of leaf surface.

Although light intensity is abundant during the summer, particularly in the southern regions of the country, it is generally deficient during the winter. As a result, the rate of photosynthesis is lower in the winter than in the summer. Because of this reduced photosynthesis, light intensity is, in general, the limiting factor in growth in greenhouses and hotbeds during the winter. In fact, scientists have found that supplemental light from incandescent lamps given in the winter accelerates the growth and flowering of certain greenhouse crops. Examples are aster, pansy, calendula, lily, snapdragon, sweet pea, phlox, and dahlia.

Light Quality. Light from the sun consists of non-visible and visible radiation. Its spectrum varies from about 291 millimicrons to 5000 millimicrons (one millimicron equals one one-millionth of a millimeter). The ultraviolet rays are the shortest and vary in length from 291 to 400 millimicrons. The infrared rays are the longest and vary in length from 720 to 5000 millimicrons. The visible spectrum is between the ultraviolet and the infrared rays and consists of several rays: violet (400 to 432 millimicrons), blue (432 to 490 millimicrons), green (490 to 575 millimicrons), yellow (575 to 595 millimicrons), orange (595 to 626 millimicrons), and red (626 to 720 millimicrons). Hence, the quality of light refers to the length of the wave.

How does the quality of light influence the growth and development of plants? Investigations have shown that the entire visible spectrum is necessary for plant growth. In other words, plants grow better in the entire visible spectrum than in any aggregation of its parts. If a plant is grown in blue light only, it develops normal leaves and stems but it has a marked stunted appearance. On the other hand, if a plant is grown in yellow light only, it develops spindling stems with long internodes and small leaves. Scientists believe that the blue end of the spectrum is necessary for the formation of chlorophyll and for the proper maturation of the plant's tissue, and that both the red and the blue part of the spectrum are necessary for photosynthesis.

The influence of the non-visible regions is known less extensively than that of the visible region. Despite the popular opinion that ultraviolet light

is beneficial to the growth of plants, investigations have shown that ultraviolet light near the visible end of the spectrum has no advantage in increasing dry weight or in hastening the time of flowering. For example, at the U.S. Horticultural Station, Beltsville, Maryland, tomato and pepper plants were started in hotbeds covered with ultraviolet-transmitting glass and hotbeds covered with ordinary glass. There were no practical differences in behavior between the two lots. The plants started under ordinary glass grew as rapidly and produced the same yields as those started under glass admitting ultraviolet light.

Light Duration. Light duration, technically known as the photoperiod, refers to the length of the day. It varies with the season and the latitude—the distance from the equator. In temperate regions the days are short during the winter and long during the summer. At the equator there are about 12 hours of day and 12 hours of night during the entire year. At the poles there are 24 hours of light during the summer and 24 hours of darkness during the winter. Consequently, as between the North and the South the photoperiod is longer in the North from March 22 to September 20 and longer in the South from September 22 to March 20. Note the day-length curves for the three locations in Figure 25.

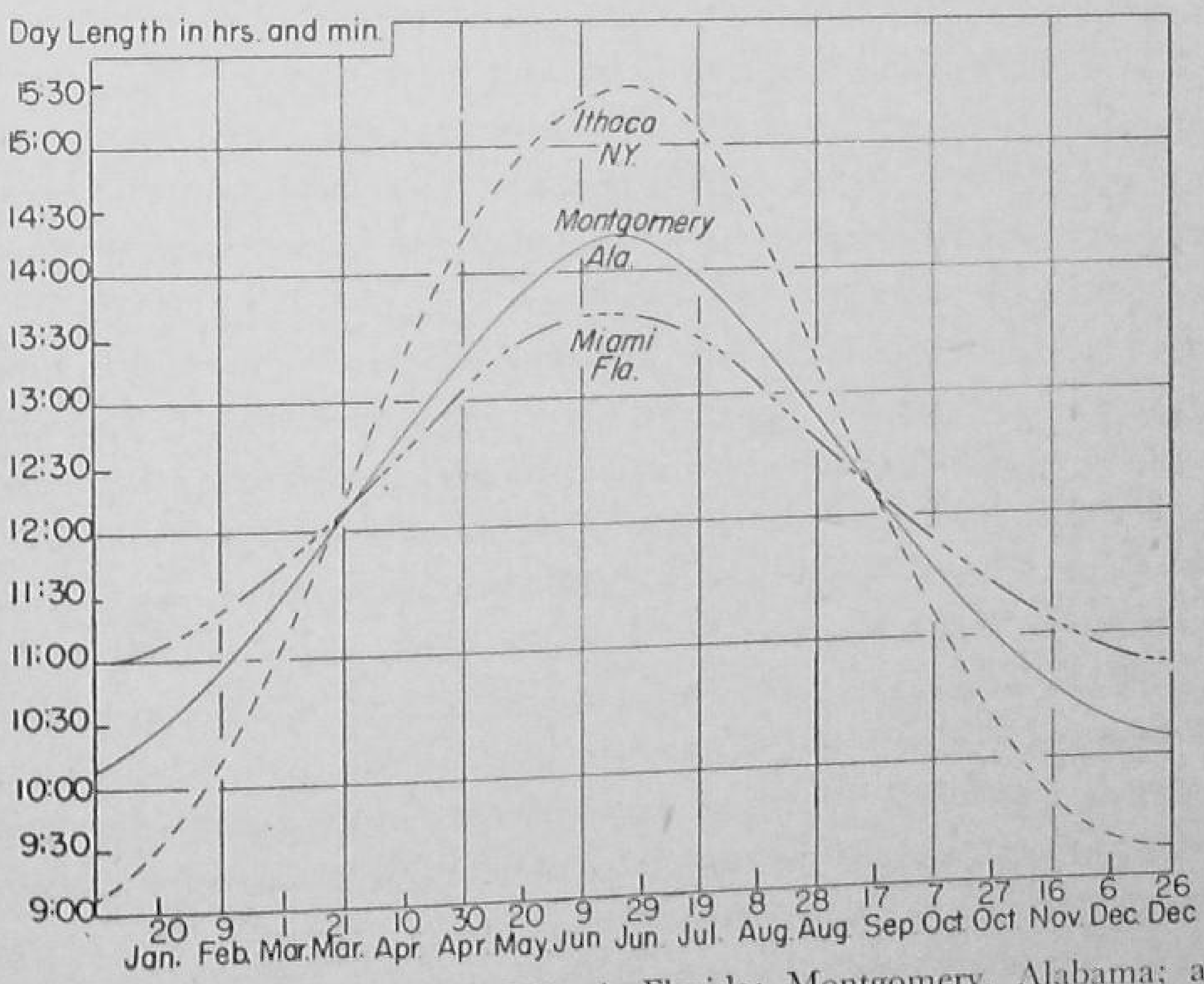

FIG. 25. Day-length curves for Miami, Florida; Montgomery, Alabama; and Ithaca, New York. (Courtesy, F. W. McElwee, Mississippi State College.)

How does light duration influence plant growth? Naturally, the length of the day influences both photosynthesis and transpiration. Of these processes, it has the greatest effect on photosynthesis. Since light energy is necessary for the combination of carbon dioxide and water in the photosynthesis reaction, the longer the length of the day, provided other factors are favorable, the greater will be the amount of foods made. Thus, a plant exposed to a favorable illumination of 16 hours will make a greater amount of food per day than a comparable plant exposed to the same favorable illumination for 10 hours.

Light Duration and Vegetation and Reproduction. Light duration not only affects the amount of food that a plant makes, but it also determines the time at which many plants flower. Many investigators have studied these length of day effects. They have found that some plants, for example spring radish and delphinium, flower during the long days only; other plants, for example certain varieties of chrysanthemum, flower during the short days only; and other plants, for example the tomato, flower during both the long and the short days. Plants which flower during long days only are called *long-day* plants; those which flower during short days only are called *short-day* plants; and those which are not influenced in time of flowering by the length of the day are called *day-neutral* plants. In general, most short-day plants require from 10 to 14 hours for flower production, and most long-day plants require from 14 to 16 hours.

When short-day plants are grown during long days, they manufacture abundant carbohydrates and make abundant proteins. These in turn are used for the development of the stems and leaves. Thus, short-day plants grown during long days are extremely vegetative, non-flowering, and non-fruitful. On the other hand, when long-day plants are grown during the short days, they manufacture very little carbohydrates and in turn make few proteins. Thus, long-day plants grown during short days, because of the lack of light, are weakly vegetative and non-flowering.

This influence of the length of the day which controls the flowering and fruiting of both long-day and short-day plants seems to be extremely localized. For example, if short-day varieties of cosmos are grown during the long day and the tips of certain branches are covered with black cloth to shorten the length of day to 9 or 10 hours, the buds so treated will develop into flowers while the branches, which were not covered, will continue to elongate.

Just how the length of day controls the flowering of long-day and short-day plants is not definitely known. One explanation is that the length

of day controls the time when protein synthesis takes place. For example, experiments have shown that certain species of salvia are short-day plants. These plants accumulate nitrates and carbohydrates in their tissues during short days. Apparently, the short days have limited the synthesis of proteins, which, in turn, has limited the making of protoplasm and the development of new cells. Because of the limited protein synthesis the carbohydrates have accumulated. This in turn has resulted in the formation of chemical compounds which are associated with the laying down of flower bud primordia.

The length of the day not only influences the time of flowering of certain plants, but it also influences the time of formation of certain storage organs. Examples are the development of bulbs of the onion and tubers of the potato. Investigations have shown that comparatively short days favor the development of tubers of certain varieties of the potato, that comparatively short days (10–11 hours) are required for the formation of bulbs of the Bermuda onion, while longer days (14–16 hours) are necessary for the formation of bulbs of American types. A brief list of short-day, long-day, and day-neutral plants is presented in Table 12.

Table 12

SOME SHORT-DAY, LONG-DAY, AND DAY-NEUTRAL PLANTS

Group	*Short-day*	*Long-day*	*Day-neutral*
Fruits	strawberries		strawberries (everbearing)
Vegetables	potato (certain varieties), sweetpotato, multiflora bean	spinach, radish, lettuce	tomato, pepper, okra
*Ornamentals ..	chrysanthemum (certain varieties), bouvardia, cosmos, stevia, poinsettia	calendula, China aster, feverfew, gardenia, delphinium, stock	carnation, cyclamen, dianthus, violet

*Brief list only. For a more complete list see Laurie, Alex and Poesch, G. H.: Photoperiodism: The value of supplementary illumination and reduction of light on flowering plants in the greenhouse, *Ohio Agr. Exp. Sta. Bul. 512*, 1932.

The florist has found practical use for the differential response of flower crops to the length of day. These practical aspects of increasing or decreasing the length of day were first investigated at the Ohio Experiment Station. The results show that many long-day plants will flower earlier than normally if given four hours of additional light in the green-

house during the winter months, and that certain short-day plants will flower earlier than normally if covered with cloth during the long days. Many commercial chrysanthemum growers are now shortening the length of day during the summer to produce blooms in advance of the natural flowering season. Under natural conditions many varieties of chrysanthemums grown in the United States flower in October. By shortening the length of day through the use of black sateen cloth, these varieties of chrysanthemums produce flowers in August and September. In this way, the marketing season for chrysanthemums is considerably lengthened. Figures 26 and 27 show the use of black cloth and supplementary light in the commerical production of greenhouse crops.

Inter-relation of Temperature and Light. Results of certain studies show an inter-relation between the temperature range at which plants are grown and light, both as to length of day and as to light intensity. A striking example is the behavior of the garden beet. This crop is a biennial. The first year the plant develops an enlarged vegetative structure called the root and the second year it develops flowers and seed. If young plants of the garden beet are grown at comparatively low temperatures, 40° to 50° F., they will produce flowers and seed without forming an enlarged root in both long and short days. On the other hand, if young plants of the beet are grown at somewhat higher temperatures, 50° to 60° F., they require

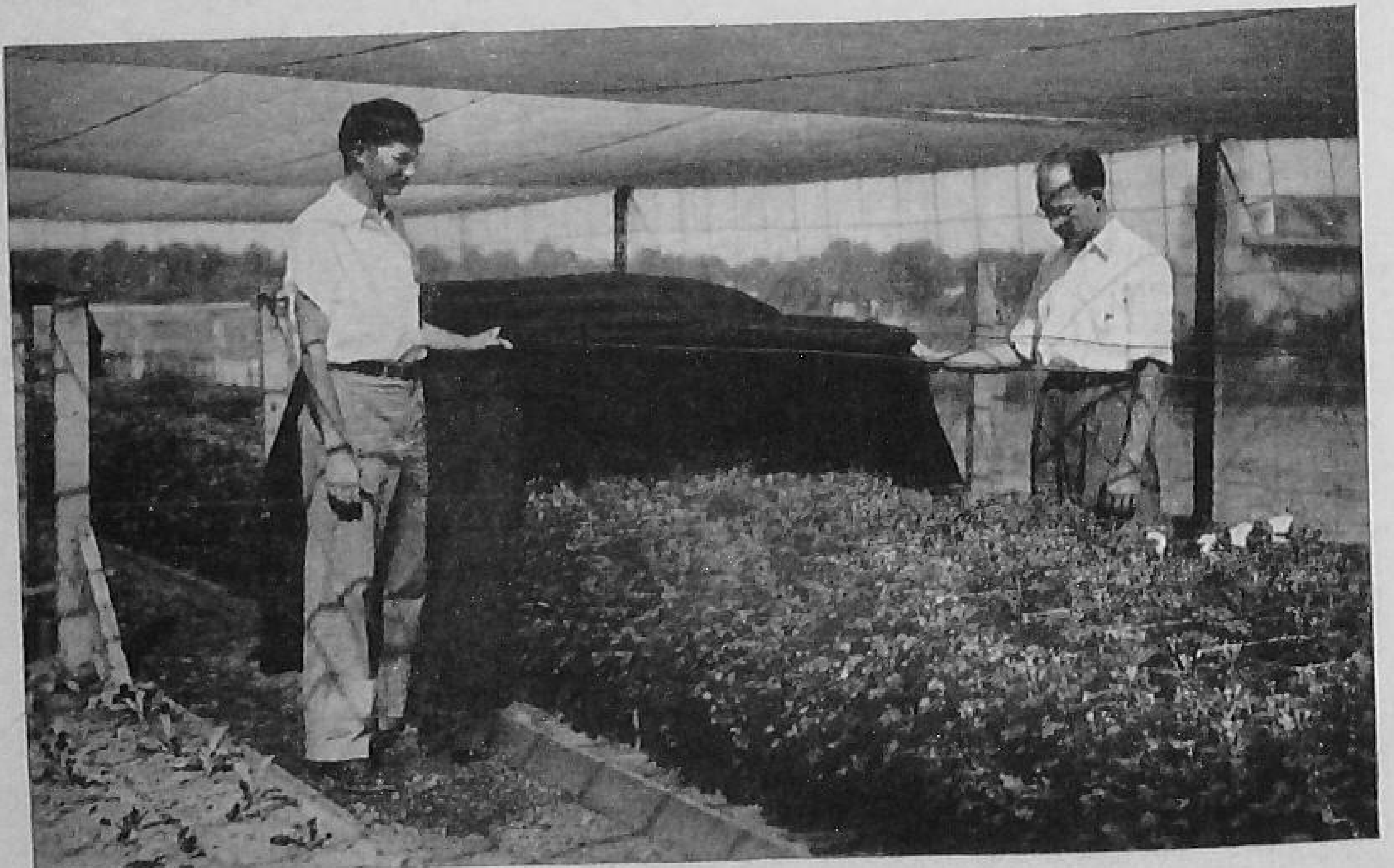

Fig. 26. An installation showing the use of black cloth to shorten the length of the day. (Courtesy, Alex Laurie, Ohio State University.)

FIG. 27. An installation showing the use of electric lights to increase the length of the day. (Courtesy, Alex Laurie, Ohio State University.)

a long photoperiod to produce flowers and seed. Thus, the higher the temperature under which the plants were grown, the longer was the photoperiod required for flower and seed production.

Variations in light intensity and light duration also influence the sex expression of many plants. As an example take cucumbers, cantaloupes, and squash. These crops are monoecious; that is, staminate and pistillate flowers are borne on the same plant. During the summer months the number of the staminate flowers greatly exceeds that of the pistillate flowers. Under these conditions, the staminate-pistillate ratio is quite wide. However, during the winter months, when temperatures and light intensity are low and the days are short, the number of staminate flowers is frequently lesser than that of the pistillate flowers. Under these conditions, the staminate-pistillate ratio is quite narrow. Evidently high temperature, high light intensity, and long days combine to promote the development of a large number of staminate flowers; and low temperatures, low light intensity, and short days combine to promote the development of a large number of pistillate flowers.

Questions

1. What is light?
2. State the function of light in photosynthesis.
3. Define light intensity.

4. Within limits, increases in light intensity increase the rate of photosynthesis. Explain.
5. Light is generally the limiting factor in growing plants in greenhouses during the winter months. Explain.
6. Plants grown in dense shade have less extensive root systems than those grown in the sun. Explain from the standpoint of the light supply.
7. The amount of light reaching the interior of thick topped apple trees is from 1 to 10 per cent of that reaching the top of the trees. The fruiting wood in the interior of such trees is thin, weak, and unproductive. Explain.
8. The sugar content of many fruits, apples, peaches, grapes, and cantaloupes is positively associated with the amount of sunshine during the period of fruit growth. Explain.
9. Under what conditions is light intensity likely to be harmful? Explain.
10. For the raising of certain crops in greenhouses lime or special shading material is placed on the roof in the spring and summer; for the same crops it is removed in the fall and winter. Explain.
11. In general, the propagating houses of florists are more heavily shaded than other houses. Explain.
12. A bright sunny fall is more favorable for the winter conditioning of woody plants than a cloudy fall. Explain.
13. Under conditions of high temperature and high light intensity certain flower crops grown in cloth houses produce thicker stems and larger flowers than those grown outdoors. Explain.
14. Define light quality.
15. A commercial gardener writes: "Do glass substitutes advertised in farm journals grow better plants than glass sash?" Give your reply based on experimental evidence.
16. Define light duration.
17. When do the equinoxes occur? How long is the photoperiod on these dates?
18. Under favorable conditions, plants make more sugars in long days than in short days. Explain.
19. What is: a short-day plant? a long-day plant? a day-neutral plant?
20. A home gardener writes: "I have been growing a certain variety of pole bean for a number of years. I find it never produces pods until October. I have tried to make it produce pods by growing the plants in different soils and in different locations on the farm but with little success." Can you give any explanation?
21. The same varieties of chrysanthemums bloom earlier in southern United States than in northern United States. Explain.
22. Would you expect onions to grow satisfactorily in the New Hebrides or in the Solomons? Explain.
23. In home gardens spinach is grown during late fall, winter, and early spring. Explain from the standpoint of the light supply.
24. How does the commercial florist lengthen the marketing season of large-headed varieties of chrysanthemums? Explain.

6

The Nutrient Supply

Assignment 9

The green plant may be considered a manufacturing establishment. Certain relatively simple compounds are used, either directly or indirectly, to make the relatively complex foods—the carbohydrates, the proteins, and the fats. The relatively simple compounds supply elements which are necessary for plant growth and development, and, because these substances can be used by plants, they are called *nutrients*. For example, all plants require nitrogen for growth and development. Nitrogen is, therefore, essential for plant growth. Although nitrogen exists in many forms, plants can absorb nitrogen only in the form of ammonium-nitrogen and nitrate-nitrogen. Ammonium-nitrogen and nitrate-nitrogen are, therefore, nutrients. Thus, *plant nutrients are substances which can be absorbed by plants and which contain one or more elements essential for plant growth.*

Of the nutrients which supply the elements necessary for growth and development, one is found in the atmosphere and the remainder are derived from the soil. Since any one of these nutrients may be a limiting factor in growth and development, the student should learn their role in plant life, how to recognize symptoms of nutrient deficiency, and when and how best to replenish the supply. The principal nutrients are: (1) Carbon dioxide, (2) water, (3) nitrate-nitrogen and ammonium-nitrogen, (4) certain phosphates, and (5) certain compounds supplying potassium, calcium, sulfur, magnesium, iron, manganese, boron, zinc, copper, and molybdenum.

CARBON DIOXIDE

Carbon dioxide supplies carbon and possibly oxygen. Carbon is necessary for the formation of all organic compounds and consists of approximately 50 per cent of the dry weight of most plants. In fact, carbon is the main element of most organic compounds.

The carbon dioxide supply is found in the atmosphere. In general, the gas exists in relatively low concentration, about 3 parts in 10,000 parts by volume in open fields and in somewhat larger amounts in greenhouses and hotbeds. Carbon dioxide gets into the plant by the process of diffusion. As long as photosynthesis is taking place, the gas diffuses from the atmosphere through the stomata and into the intercellular spaces of the chlorophyll-containing cells. On the surface of these cells carbon dioxide enters into solution with water, diffuses to the surface of the chloroplasts, and finally unites with water in the presence of light to form sugars and related substances.

Although the concentration by volume of carbon dioxide in the atmosphere is relatively small, the actual amount present is enormous. Scientists have estimated that the total quantity of carbon dioxide in the atmosphere is 2×10^{15} kilograms and that 60 million million kilograms are used annually by green plants in photosynthesis. Despite this enormous quantity used in photosynthesis, the total amount of carbon dioxide in the atmosphere remains relatively constant. How is the carbon dioxide supply replenished? Carbon dioxide is released to the atmosphere by two similar processes: (1) The respiration of all living organisms and (2) the combustion of organic compounds. The student should note that living organisms include both green and non-green plants and animals on the land, and both green and non-green plants and animals in the waters of the earth. Tremendous quantities of carbon dioxide are released to the atmosphere by the billions of fungi and bacteria in the soil and by the billions of living things on the land and in the oceans, lakes, and rivers.

When is the concentration of carbon dioxide likely to be the limiting factor in photosynthesis and in plant growth and development? In general, when other factors influencing photosynthesis are in abundant supply, carbon dioxide is the limiting factor. This condition is likely to occur when temperatures are within the optimum range, when the light supply is abundant, and when the plant is supplied with abundant water and nutrients. With these optimum conditions, investigations have shown that an enrichment of the air with carbon dioxide increases plant growth. The

tests with this nutrient were conducted in greenhouses where the carbon dioxide supply could be more or less confined, and when other environmental factors were not limiting in growth. In one experiment cucumbers supplied with air consisting of 31.3 parts of carbon dioxide in 10,000 parts by volume increased 60.0 per cent in dry weight over those supplied with 3.0 parts of this gas in 10,000 parts—the usual concentration. In another test potatoes, tomatoes, beets, and carrots showed significant increases in growth. In general, increases in the concentration of carbon dioxide from 0.03 per cent to 0.3 per cent by volume have increased the rate of photosynthesis until some other factor has become limiting in growth. At present the artificial use of carbon dioxide as a nutrient is in the experimental stage, and is of interest mainly to scientists and to growers of plants in the greenhouse.

WATER

Water is a plant nutrient. It supplies hydrogen and oxygen. Hydrogen is necessary for the formation of the principal foods—the carbohydrates, proteins, and fats—and determines the energy value of these foods. Foods which are high in hydrogen in proportion to oxygen have a higher energy content than those which have a low amount of hydrogen in proportion to oxygen. For example, fats have a relatively higher hydrogen content than carbohydrates. When completely oxidized 1 gram of fat gives off 9.3 calories of heat while 1 gram of starch gives off 4.1 calories. In addition to furnishing hydrogen and oxygen water has many other roles in plant life. These are discussed in Chapter 3.

NITRATE-NITROGEN AND AMMONIUM-NITROGEN

Nitrate-nitrogen and ammonium-nitrogen supply nitrogen. Plants cannot absorb nitrogen in any other form. For this reason, nitrate-nitrogen and ammonium-nitrogen are called the available forms of nitrogen. *Nitrogen enters into the formation of all proteins.* In fact, the manufacture of proteins may be considered a part of the photosynthetic process. Certain sugars and compounds containing nitrogen combine to make proteins. As previously stated, proteins are necessary for the making of protoplasm.

Although proteins are synthesized in many parts of the plant, most of them are made in the growing points, and in the cambium tissue. As stated before, these tissues require large quantities of nitrogen since in these tissues new protoplasm is made. Thus, when a plant is developing

its stems, leaves, and root system, comparatively large quantities of available nitrogen are necessary.

The Available Nitrogen Supply and the Vegetative-Reproductive Balance. As previously stated, sugars and nitrogen combine to form proteins; these substances are necessary for the formation of protoplasm; and when a plant is making new protoplasm it is making new cells. It follows, therefore, that with other factors favorable for growth, the available nitrogen supply will determine the rate at which new cells are made and the rate at which sugars are used. Thus, if a plant has a high rate of photosynthesis and absorbs *large* quantities of available nitrogen, and is subjected to temperatures within the upper half of the optimum range, the sugars will be used almost entirely for the production of stems, leaves, and absorbing roots. If, on the other hand, the plant has a high rate of photosynthesis and absorbs *moderately large* quantities of available nitrogen, the development of stems and leaves will be less rapid, and as a result there will be less rapid utilization of sugars for stem, leaf, and root growth. Some sugars will be left for the development of flower-forming substances and flowers, fruit, and seed. Thus, the amount of available nitrogen may regulate the type of growth provided other factors are not limiting. In general, with abundant carbohydrates and abundant available nitrogen, vegetative processes will be dominant over reproductive processes. With abundant carbohydrates and moderately abundant available nitrogen, vegetative processes will be less dominant and reproductive processes will be more evident.

Symptoms of Nitrogen Deficiency and Excess. Since large or small quantities of available nitrogen may exist in the soil solution, the student should become familiar with the symptoms of nitrogen deficiency and the symptoms of nitrogen excess. Symptoms of nitrogen deficiency with most plants are as follows: growth processes gradually slow down, the older leaves become yellowish green, the red pigments are often conspicuous, and fruits, when present, are few and small. The plants are stiff and woody and they possess thick cell walls, well-developed fibers, and thick cuticle and epidermis. The root system is extensive and much branched. These woody, non-succulent stems contain a high concentration of reserve carbohydrates, usually starch. Figure 28 shows leaf blades of a nitrogen-deficient gardenia. Note the uniform yellowing of the blade.

Symptoms of nitrogen excess with most plants are as follows: growth processes proceed rapidly. In other words, there is a rapid development of stems and large dark green leaves. The red pigments are usually absent.

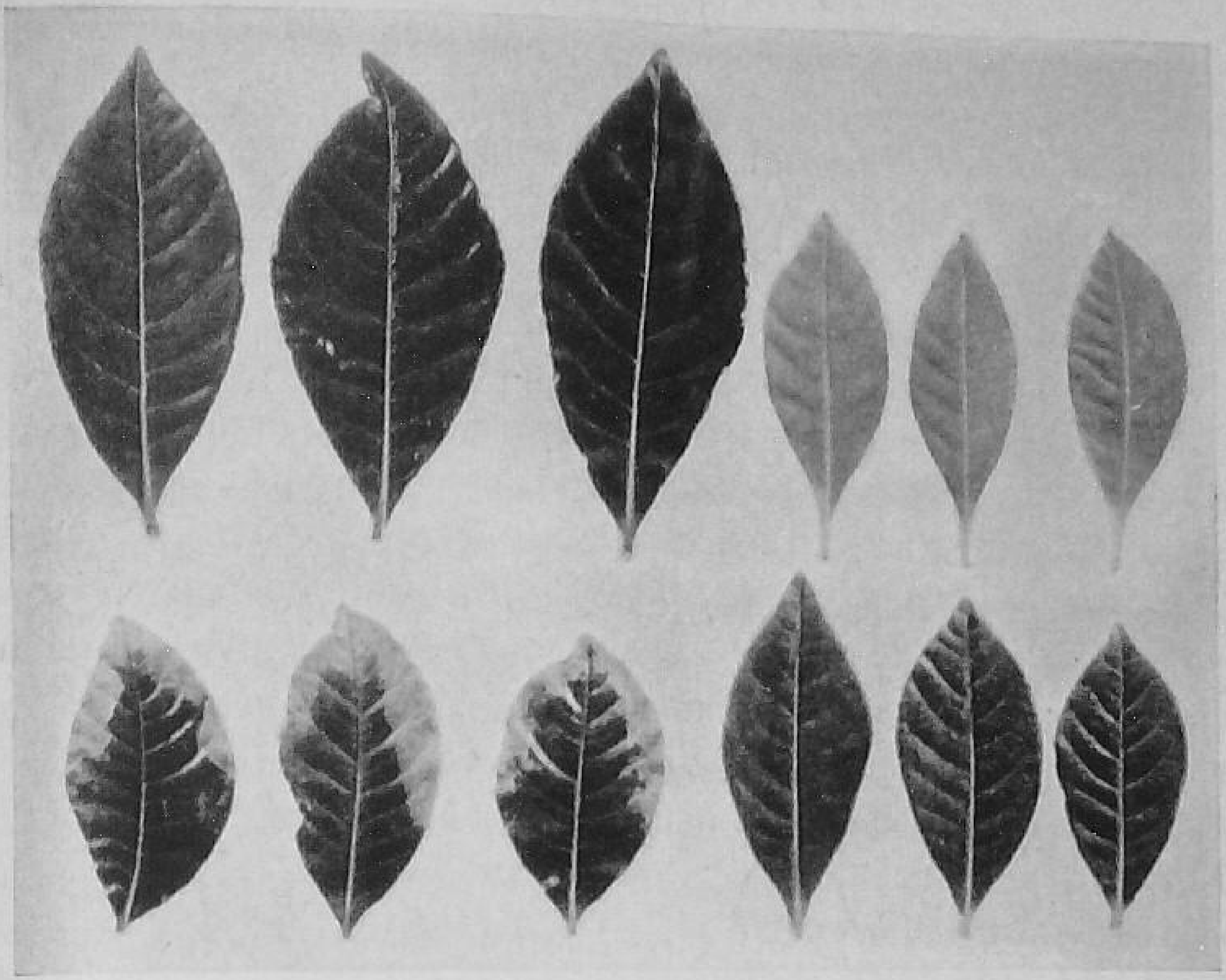

Fig. 28. Nitrogen-, phosphorus-, and potassium-deficient leaves of gardenia. (*Upper left*) Healthy. (*Upper right*) Nitrogen-deficient. (*Lower left*) Potassium-deficient. (*Lower right*) Phosphorus-deficient. (Courtesy, Alex Laurie, Ohio State University.)

The fruits are large and lack color for the variety. The stems are soft and succulent. The cell walls are thin and the development of fibers is limited. These succulent stems fail to store carbohydrates.

Form Used by Plants. As previously stated, plants absorb nitrogen in the form of ammonium-nitrogen or nitrate-nitrogen. In acid soils plants seem to prefer nitrate-nitrogen; in slightly alkaline soils they seem to prefer ammonium-nitrogen. For example, scientists at the New Jersey Experiment Station supplied apples and tomatoes with equal amounts of nitrate and ammonium-nitrogen growing on very acid (pH 4.0), moderately acid (pH 6.0), and neutral soils (pH 7.0). On the acid soil (pH 4.0) the apple trees and tomato plants assimilated the nitrate form to a greater extent than the ammonium form. On the neutral soil (pH 7.0) they assimilated the ammonium form to a greater extent than the nitrate form, and on the moderately acid soil (pH 6.0) they assimilated both forms in practically equal amounts. Apparently, the relative amount of ammonium-nitrogen or nitrate-nitrogen which is assimilated depends on the soil reaction. Each form behaves differently in the soil. Ammonium-nitrogen is fixed slightly

and nitrate-nitrogen is leached readily. Which form will be more readily lost by heavy rains or excessive irrigation?

Natural Sources of Available Nitrogen. The natural sources of supply are: (1) Nitrogen in organic matter and (2) nitrogen in the atmosphere.

NITROGEN IN ORGANIC MATTER. The nitrogen in organic matter is in the form of protein-nitrogen. As such plants cannot use it, it must be changed to the ammonium or nitrate form. Certain fungi and bacteria effect this change. These organisms are minute plants, and, since they lack chlorophyll, they must obtain their energy from sources other than the sun. To obtain this energy they decompose the organic matter. Vast numbers of these organisms exist in the soil. Bacteriologists have estimated that as many as 46 billion bacteria exist in a gram of decomposing material. Under average conditions a fertile soil contains from one-half to one ton per acre of these organisms or about 100 to 250 billion per pound of soil. Obviously, these organisms have an important role in the growing of all plants.

Two sets of organisms are necessary to complete the change of protein-nitrogen to nitrate-nitrogen. The first group comprise certain fungi and bacteria and are called the ammonifiers. They change the protein-nitrogen to ammonia. The second group are bacteria only and are called the nitrifiers. They change the ammonia to nitrites and finally to nitrates. The changes are biochemical and are illustrated as follows:

$$\text{protein N} \longrightarrow \text{amino acids} \xrightarrow{\text{(fungi and bacteria)}} NH_3 + CO_2 + H_2O + \text{energy}$$

$$NH_3 \xrightarrow[(\textit{Nitrosomonas})]{+O_2} 2\ NO_2 + \text{energy}$$

$$2\ NO_2 \xrightarrow[(\textit{Nitrobacter})]{+O_2} 2\ NO_3 + \text{energy}$$

NITROGEN IN THE ATMOSPHERE. The nitrogen in the atmosphere is in the form of gaseous nitrogen. As such, higher plants cannot use it. As in the case of protein-nitrogen, before this gaseous nitrogen can be used by plants it must be changed to the ammonium or nitrate form. Certain microörganisms effect this change. Two distinct groups of bacteria do this: (1) Non-symbiotic* and (2) symbiotic.*

The non-symbiotic bacteria live independently of green plants and

*The word symbiosis means living with other kinds of organisms to mutual advantage.

possess the ability to use gaseous nitrogen directly. Two prominent genera of these bacteria are *Azotobacter* and *Clostridium*. They use the gaseous nitrogen to form their body proteins. When these bacteria die their protein-nitrogen is broken down to amino acids, ammonia, and nitrate-nitrogen from organic matter.

The symbiotic bacteria live in conjunction with a certain group of higher plants which, because of their characteristic fruit, are called legumes. The bacteria have been placed in the genus *Rhizobium*. They change the gaseous nitrogen to assimilatory nitrogen, which in turn is used by the leguminous plant. In return for this nitrogen the higher plants supply the bacteria with the necessary carbohydrates. This is a fine example of mutual coöperation or symbiosis. Note the nodules of the nitrogen-fixing bacteria on the soybean in Figure 29.

Different classes of legumes require different kinds of these bacteria. The kind that is adapted to alfalfa will not grow on peas or beans and vice versa. Thus, the legumes should be inoculated with proper cultures. Within each kind scientists have found good strains and poor strains. The good strains are hard workers. That is, they supply the plant with abundant available nitrogen. The poor strains are lazy and make little or no available nitrogen in return for the carbohydrates they receive. Investigators are endeavoring to eliminate these poor strains and to develop good strains. Agricultural experiment stations have developed quick and economical methods of mixing seeds with these bacteria—a practice known as inoculation. In general, growers have found that inoculation pays.

The changes which gaseous nitrogen undergoes to become ammonium- or nitrate-nitrogen is illustrated as follows:

$\longleftarrow$ gaseous N $\longrightarrow$	NO_3 $\longrightarrow$	protein N $\longrightarrow$	NH_3 $\longrightarrow$	NO_2 $\longrightarrow$	NO_3
(*Rhizobium*)		(legumes)	(bacteria and fungi)	(*Nitrosomonas*)	(*Nitrobacter*)

Conditions Affecting the Activities of Assimilatory Nitrogen-making Bacteria. If the fungi and bacteria which help make nitrate-nitrogen and ammonium-nitrogen were non-existent, the farmer's bill for nitrogen fertilizers would be enormously increased. In other words, these fungi and bacteria make large quantities of available nitrogen, a quantity which certain scientists have estimated as varying from 50 to 300 pounds per acre per year. Their activity is markedly affected by the environment. The principal environmental factors are: (1) Temperature, (2) moisture, (3) oxygen supply, and (4) acidity of the soil.

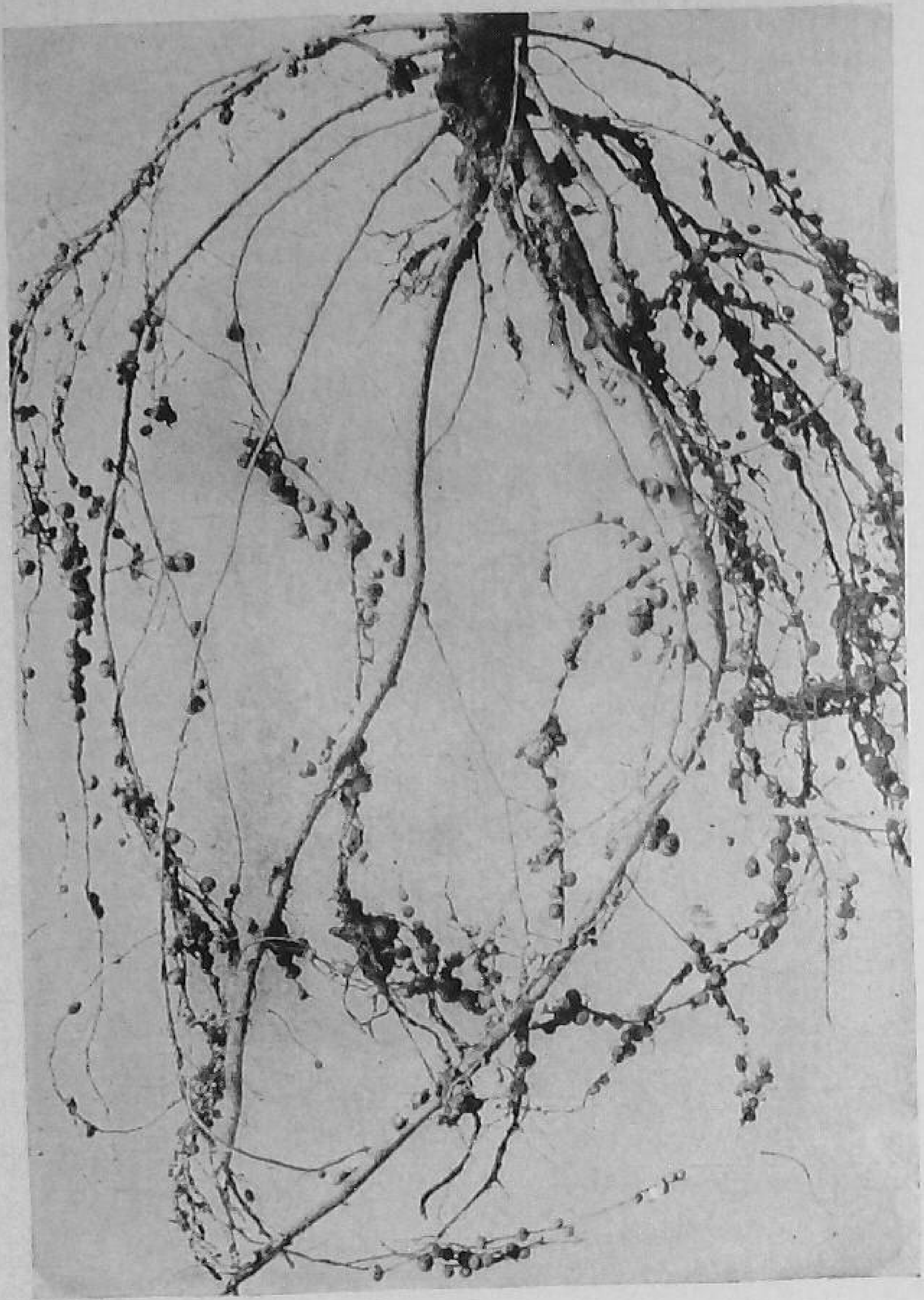

FIG. 29. Nodules of nitrogen-fixing bacteria on roots of soybean. (Photo by U.S. Department of Agriculture. Courtesy, Emerson, F. W.: "Basic Botany," Philadelphia, The Blakiston Company.)

TEMPERATURE. Temperature affects the activity of the ammonia and nitrate makers in much the same way as it affects higher plants. When the soil is cold or extremely hot their activity is retarded. Temperatures for their greatest activity are moderately high (60° and 85° F.). Consequently, the curve of nitrate-nitrogen formation, other factors being equal, varies with the temperature of the season, the locality, and the soil.

MOISTURE. A moist soil is more favorable than a dry soil. The effect of moisture is twofold: (1) It aids in the decomposition of organic matter and (2) it brings necessary nutrients into solution. Bacteria and fungi

require mineral nutrients for growth in much the same way as higher plants. These nutrients must be in solution before their absorption into the cells can take place.

Oxygen. Abundant supplies of oxygen are necessary for the respiration of all the ammonium- and nitrate-nitrogen makers. For this reason soils should be well drained. In fact, non-aerated, poorly drained soils contain certain bacteria called *Bacillus denitrificans.* These organisms live in the absence of free oxygen. They obtain their oxygen requirements from nitrates which are decomposed to nitrogen and oxygen. Fortunately, these organisms do not thrive in well-drained soils. The decomposition of nitrate-nitrogen is illustrated as follows:

$$2HNO_3 \longrightarrow 2N + H_2O + 2\tfrac{1}{2}O_2$$

Acidity of the Soil. Investigations have shown that the nitrifying organisms cannot live in very acid soils. The optimum reaction range seems to be from pH 6.0 to 6.8. Thus, satisfactory nitrate formation does not take place in very acid or alkaline soils.

In general, these ammonia and nitrate makers work best when the soil is moderately warm, moist, slightly acid, well aerated and well drained. Any deviation from these desirable conditions will correspondingly reduce the available nitrogen supply.

The student should remember that the process of changing protein-nitrogen to ammonium- and nitrate-nitrogen depletes the soil of its potential supply. For the satisfactory growth of economic crops the addition of potential supplies is necessary. This can be done in two ways: (1) By the addition of organic matter in the form of either manure or cover crops and (2) by the application of nitrogenous fertilizers—practices which are discussed in Chapters 9 and 10.

Artificial Sources of Nitrogen Fertilizers. Despite the relatively large amounts of available nitrogen made by soil organisms, only in exceptional cases are there quantities sufficient for the satisfactory growth of crop plants. Thus, artificial applications are necessary.

From the standpoint of their effect on the soil and plants, nitrogen carriers are classified as follows: (1) Physiologically acid and (2) physiologically alkaline. In *physiologically acid* carriers plants absorb the cation to a greater extent than the anion. In *physiologically alkaline* carriers plants absorb the anion to a greater extent than the cation. The continued use of the former makes soils more acid, and the continued use of the latter makes soils more alkaline. Consequently, the choice of either type of

fertilizer depends to some extent on the soil reaction. Several acid- and basic-forming carriers are shown in Table 13.

Table 13

ACID AND BASIC NITROGEN CARRIERS

Acid-forming Carriers	N *Per Cent*	*Basic-forming Carriers*	N *Per Cent*
Ammonium sulfate	21	Sodium nitrate	16
Urea	46	Cyanamide	22
Ammo phos	11	Calcium nitrate	16
Dried blood	13	Tankage	3

PHOSPHATES

Plants absorb phosphorus only in the form of phosphates—a highly oxidized state. *Phosphorus is essential for the formation of certain nucleic acids contained in the nucleus, for the formation of certain proteins, and for the formation of starch,* since many plants fail to store this material in its absence.

Symptoms of Phosphorus Deficiency. Although symptoms of phosphorus deficiency are not so striking as those of nitrogen deficiency, a lack of phosphorus is indicated by a slowing down of growth and by late maturity. The young leaves are dark green or grayish green. The stems or twigs are slender and often woody. The roots are underdeveloped. In fruit trees the blossoms drop off, the fruit is small, unattractive in color, and matures slowly, and few fruit buds are formed for the next year's crop. Usually, the stems are high in sugars and low in starch. Since phosphorus is re-utilized, the old leaves show symptoms of phosphorus deficiency before the young leaves. Note the phosphate–phosphorus-deficient leaf blades in Figure 28.

Sources and Availability. The chief sources are tricalcium phosphate and basic slag. Tricalcium phosphate exists in the form of raw rock phosphate and bone meal. These natural forms are relatively insoluble and relatively unusable by plants. Thus, they must be changed to more soluble and usable forms. These forms are monocalcium phosphate, $CaH_4(PO_4)_2$ and dicalcium phosphate, $Ca_2H_2(PO_4)_2$. The dicalcium form is soluble in dilute citric acid and the monocalcium form is soluble in water. Both forms are available to plants. These available forms are secured by treating raw rock phosphate with sulfuric acid or phosphoric acid. Note the equations.

$$2Ca_3(PO_4)_2 + 3H_2SO_4 \longrightarrow Ca_2H_2(PO_4)_2 + CaH_4(PO_4)_2 + 3CaSO_4$$

(relatively insoluble) (relatively soluble)

$$Ca_3(PO_4)_2 + 4H_3PO_4 \longrightarrow 3\ CaH_4(PO_4)_2$$

The treatment of raw rock phosphate with sulfuric acid produces a mixture of three compounds—monocalcium phosphate, dicalcium phosphate, and gypsum called superphosphate. This material varies from 16 to 20 per cent P_2O_5 depending on the relative amount of the phosphate salts and gypsum in the mixture.

The treatment of raw rock phosphate with phosphoric acid produces monocalcium phosphate only. In this way the production of gypsum is eliminated. The product is called double or treble superphosphate and varies from 40 to 50 per cent P_2O_5.

Behavior in Soil. In most soils monocalcium phosphate changes to the dicalcium state.

$$CaH_4(PO_4)_2 \longrightarrow Ca_2H_2(PO_4)_2$$

In soils high in calcium the dicalcium form changes to the tricalcium form.

$$Ca_2H_2(PO_4)_2 + CaCO_3 \longrightarrow Ca_3(PO_4)_2 + H_2CO_3$$

In acid soils less than pH 5.0 where abundant iron or aluminum silicates exist the dicalcium form changes to insoluble iron or aluminum phosphate.

$$Ca_2H_2(PO_4)_2 + 3Fe \longrightarrow \underset{\text{(insoluble)}}{Fe_3(PO_4)_2} + \underset{\text{(soluble)}}{2CaHCO_3}$$

$$Ca_2H_2(PO_4)_2 + 3Al \longrightarrow \underset{\text{(insoluble)}}{Al_3(PO_4)_2} + \underset{\text{(soluble)}}{2CaHCO_3}$$

Thus, the reaction of the soil largely determines the availability of the phosphates. Research work at the Truck Experiment Station at Norfolk, Virginia, has shown that the range of maximum availability of phosphates of the soils in that region is between pH 5.5 and 6.8.

In the rich soils of greenhouses, applications of bone meal often produce as good results as applications of superphosphate. In these soils the tricalcium form in bone meal is changed to the dicalcium form through the reaction of carbonic acid. Where does the carbonic acid come from? The organic matter is decomposed to carbon dioxide. This gas combines with

water to form carbonic acid which in turn combines with the bone meal to form dicalcium phosphate. The change is illustrated as follows:

$$Ca_3(PO_4)_2 + H_2CO_3 \longrightarrow Ca_2H_2(PO_4)_2 + CaCO_3$$

Unlike nitrates, superphosphate is readily "fixed" by soils. Consequently, very little movement or leaching takes place and excessive amounts in the soil solution do not exist. Therefore, phosphates can be applied when convenient and preferably in close proximity to the plant's roots. For most crops it is usually applied at the time of soil preparation and as side dressings during the early stages of growth.

Basic or Thomas slag is a by-product of the open hearth furnace in the manufacture of steel. It is placed on the market in a finely divided form and consists of phosphoric acid (10 to 25 per cent), hydrated lime (40 to 50 per cent), and small amounts of manganese and iron. The phosphoric acid is readily available to plants.

Questions

1. Distinguish between a food and a plant nutrient.
2. State the role of carbon dioxide in plant growth.
3. The concentration of carbon dioxide in the atmosphere remains practically constant. Explain.
4. Water is a nutrient. Explain.
5. Nitrogen is needed for the development of meristematic tissues. Explain.
6. Describe the symptoms of nitrogen deficiency.
7. Plants growing in soil containing deficient quantities of available nitrogen store carbohydrates. Explain.
8. A plant growing in a small pot flowers earlier than a plant growing in a large pot. Explain from the standpoint of the nitrogen supply.
9. Tomatoes and cucumbers growing in an old barnyard are frequently vigorously vegetative and begin to produce fruit late in the season. Explain.
10. Investigations at the Virginia Truck Experiment Station have shown that tomatoes fertilized with mixtures high in nitrogen are more vegetative and less productive than those fertilized with mixtures comparatively low in nitrogen. Explain.
11. Name the natural sources of nitrogen.
12. Outline the changes taking place from protein-nitrogen in organic matter to nitrate-nitrogen and from gaseous nitrogen to nitrate-nitrogen.
13. Name the factors influencing the activity of soil fungi and bacteria.

14. The natural nitrate supply is low in winter and comparatively high in summer. Explain.
15. Experiments at the Louisiana Experiment Station have shown that a complete fertilizer is necessary for the fertilization of spring crops of snap beans and a fertilizer without nitrogen is necessary for the fall crop. Explain.
16. Side dressings of quickly available nitrogen to truck crops in the seedling stage are frequently necessary during cold, wet weather. Give two reasons.
17. Decomposition of organic matter in winter in the greenhouse is more rapid than outdoors. Explain.
18. Are peas or beans inoculated in your district? Give reasons for your answer.
19. Crops started under glass in late spring, summer, and early fall can use more available nitrogen than those started under glass in late fall, winter, and early spring. Explain.
20. What is meant by: a physiologically acid fertilizer? a physiologically alkaline fertilizer?
21. Show: how the continual use of a physiologically acid fertilizer makes the soil more acid; how the continual use of a physiologically alkaline fertilizer makes the soil less acid and more alkaline.
22. In what state do plants absorb phosphorus?
23. Name the chief sources of phosphorus.
24. Write the chemical formulas for: raw rock phosphate; dicalcium phosphate; monocalcium phosphate.
25. Phosphorus is unavailable in soils greater than pH 8.5. Explain.
26. Phosphorus becomes unavailable in soils less than pH 5.0. Explain.
27. What is the pH range within which phosphates are generally available to plants? Explain.
28. Bone meal is most effective when used in soils high in rapidly decomposing organic matter. Explain.

Assignment 10

CERTAIN SALTS OF POTASSIUM

Certain salts of potassium, particularly potassium chloride, potassium sulfate, and potassium nitrate, supply potassium. In general, *potassium appears to be necessary for the reduction of nitrate-nitrogen in plants,* since experiments have shown that plants supplied with insufficient potas-

sium contain large quantities of nitrate-nitrogen and abundant carbohydrates. As previously stated, this reduction of nitrate-nitrogen is necessary before the nitrogen can combine with sugar to form proteins.

Symptoms of Potassium Deficiency. The symptoms of potassium deficiency vary somewhat with different crops. With fruits—apple, pear, plum, gooseberry, and black and red currant—potassium deficiency is first diagnosed by a faint yellowing of the leaf margins. Later the yellowing proceeds along the veins and the margins turn dark brown. This condition is known as scorch. It is very serious in Great Britain, Quebec, and Nova Scotia, and occurs to some extent in northern United States. With citrus crops the branches droop and the leaves become "stitched." With cucumbers the margins of the old leaves develop a yellow color, while the midrib and veins remain green. With potatoes and sweetpotatoes the leaves become rough and puckered and the margins curl downward. In extreme cases the leaf margins turn yellow and finally brown. With tomatoes the symptoms appear first on the young leaves. They turn light yellow or yellowish green. The plants stop developing stems and leaves and accumulate starch. As the deficiency becomes severe small brown specks occur on the old leaves followed by yellowing and breaking down of the margins. The new growth is brittle and slender. With many flower crops the margins turn yellow and finally dark brown. In general, old leaves usually show the symptoms first. They remain attached to the plant. The stems become woody and slender. The flowers become small, ill-shaped, and poorly colored. Note the appearance of the margins of the leaf in Figure 28.

Sources and Behavior in Soil. Carriers of potassium are potassium chloride (KCl), potassium sulfate (K_2SO_4), both 48–50 per cent K_2O; potassium nitrate (KNO_3), 44 per cent K_2O; and kainite, 12 to 16 per cent K_2O. The soil fixes potassium to a lesser degree than it does phosphorus. Consequently, if comparatively large quantities are applied leaching will take place and excessive amounts in the soil solution will exist.

SUBSTANCES SUPPLYING CALCIUM

Plants absorb calcium in the unoxidized or unreduced state. Calcium is absolutely necessary for plant growth. This element is used in the formation of new cells. Hence, abundant quantities are found in the growing points of the root, the stem, and the leaves, and in the cambiums. Investigations have shown that calcium-deficient plants accumulate sugars and starches in the tissues and are unable to absorb nitrate-nitrogen. Im-

mediately after the calcium-starved plants are supplied with this nutrient, nitrates, if available, are found within the tissues in a relatively short time. Thus, *calcium appears to be necessary for the absorption of nitrate-nitrogen.*

Symptoms of Calcium Deficiency. Investigations at the New Jersey Experiment Station have shown that calcium-deficient plants of the Marglobe tomato become stunted, stiff, and woody. The upper leaves were yellowish green and the lower leaves remained normal green. The margins were usually less dark green than the central portion. Roots became short, bulbous, and brownish at the tips. Fruits were few. Calcium-deficiency symptoms of the apple are somewhat similar. Mature leaves are dark green and the young leaves may appear yellowish green. On young trees the leaves may be abnormally small. On large trees the leaves may be normal in size except those near the tips of twigs. In severe cases the margins of the leaves turn brown, and the growth of the roots is seriously retarded. These roots appear short, stubby, and branched at the tips. New roots may form but they live for a short time only. Investigations at the Ohio Experiment Station have shown that plants of many herbaceous flowering crops become stunted, the roots die back at the tips in a relatively short time, and the terminal buds fail to develop.

Sources and Behavior in Soil. Common carriers of calcium are the three forms of lime: calcium oxide, calcium hydroxide, and calcium carbonate. In soils calcium oxide and calcium hydroxide gradually change to calcium carbonate, according to the following equations:

$$(1)\quad CaO+HOH=Ca(OH)_2$$
$$(2)\quad Ca(OH)_2+CO_2=CaCO_3+H_2O$$

Growers usually use the hydrated or carbonate form.

Relation of Soil Acidity to Growth and Development. In addition to supplying calcium, the various forms of lime are used to make soils less acid. The acidity of the soil solution has a marked effect on the growth and development of many economic crops. If the soil solution is very acid on the one hand or alkaline on the other, growth and development of most crops is markedly reduced. In addition crops vary in their acidity requirements. Some thrive best in markedly acid soils; some thrive best in slightly acid soils; and others thrive well over a comparatively wide range of soil acidity. Since soils vary in the degree of acidity and since plants vary in their acidity requirements, the student should have a working knowledge of the factors which cause acidity, how the acidity of the soil

influences growth, and how the acidity may be modified to produce high marketable yields.

To What Are Acidity and Alkalinity Due? Any aqueous solution always contains a certain concentration of hydrogen ($\overset{+}{H}$) ions, and a certain concentration of hydroxyl ($\overline{OH}$) ions. The acidity of the solution is due to hydrogen ($\overset{+}{H}$) ions and its alkalinity is due to hydroxyl ($\overline{OH}$) ions. Water ionizes, forming hydrogen and hydroxyl ions according to the following equation:

$$H_2O \rightleftarrows \overset{+}{H} + \overset{-}{OH}$$

Thus, any solution of which water is the solvent contains water molecules, hydrogen ions, and hydroxyl ions. Scientists have developed a scale by which the degree of acidity is measured. This scale, called the pH scale, has the following characteristics: it varies from 1 to 14; the values are negative logarithms; and at pH 7, the midpoint, the solution is neutral. Since the scale consists of negative logarithms, a decrease in unit pH means a tenfold increase in H-ion concentration and a corresponding tenfold decrease in the OH-ion concentration. Thus, a solution with a pH of 5.0 has a tenfold degree of acidity of a solution with a pH of 6.0.

Soil Reaction and Nutrient Availability. A definite relation exists between soil reaction, nutrient availability, and plant growth. Nitrate formation is markedly reduced below pH 5.5, since the activity of nitrifying bacteria is markedly decreased when the pH of the soil is below this point. Mono- and dicalcium phosphate change to insoluble iron and aluminum phosphate in soils less than pH 5.0. They change to tricalcium phosphate in soils greater than pH 7.0. Potassium becomes unavailable in soils greater than pH 8.0. Aluminum becomes very soluble in soils less than pH 5.0. Iron and manganese become insoluble at a pH greater than 7.5. Calcium and magnesium are less abundant in very acid soils than in moderately acid or slightly acid soils. In other words, high hydrogen-ion concentration reduces the amount of nitrates, calcium, and magnesium, and the availability of phosphates. It increases the availability of iron, aluminum, and manganese. This increase in availability of iron and aluminum may become so great that their concentration becomes injurious to crops. On the other hand, a high concentration of hydroxyl ions, greater than pH 8.0, decreases the availability of phosphates, potassium, iron, and manganese. Thus, high acidity on the one hand and high alkalinity on the other should be avoided.

As previously stated, certain crops thrive best in slightly acid soils, pH 6.0 to 6.8; others thrive best in moderately acid soils, pH 5.0 to 6.0; and others thrive equally well on both slightly acid and moderately acid soils, pH 5.0 to 6.8. A few crops require extremely acid soils on the one hand and slightly alkaline soils on the other. The optimum pH range of certain horticultural crops based on grower's experience and the latest experimental evidence is presented in Table 14.

Table 14

Soil Acidity Requirements of Horticultural Crops

Optimum pH Range	*Crop*
Very acid (pH 4.0–5.0)	azalea, rhododendron, mountain laurel, blueberry, huckleberry, and cranberry. (Many of these plants have mycorrhizal fungi in their roots. These fungi supply the plants with nitrogen and possibly other nutrients)
Moderately acid (pH 5.0–6.0)	snap bean, potato, sweetpotato, watermelon, aster, lily of the valley, orchid, holly, juniper, lily, phlox, and hydrangea
Slightly acid (pH 6.0–6.8)	asparagus, spinach, lima bean, beet, celery, cantaloupe. lettuce, onion, sweet cherry, rose, chrysanthemum, sweet pea, and snapdragon
Slightly and moderately acid (pH 5.0–6.8)	apple, pear, peach, plum, pecan, grape, grapefruit, raspberry, blackberry, strawberry, cabbage, radish, squash, tomato, pepper, sweet corn, carrot, and carnation
Slightly alkaline (pH 7.5–8.0)	calendula and gerbera

Determining Soil Reaction. Within recent years certain experiment stations have developed comparatively simple tests to determine the reaction of the soil solution. In general, these tests involve the use of an indicator—a substance which will change color with a change of acidity of the solution. This indicator is allowed to percolate slowly through a small mass of soil and the change in color in the indicator denotes a certain degree of acidity. These tests are fairly accurate, reliable, and inexpensive, and permit making many determinations in the field in a comparatively short time.

Reducing Acidity. Many soils in many districts are too acid for the rapid growth and production of profitable crops. To reduce acidity lime is added. The amount required depends largely on: (1) Soil type, (2)

system of farming, and (3) change in pH that should be made. Since light soils are more sensitive to changes in acidity than heavy soils, due to lesser buffer capacity, comparatively light applications are needed. Crops which thrive best on slightly acid soils will require more lime than those which thrive best on moderately acid soils. The greater the change in pH that should be made, the greater will be the amount of lime required. In general, the rate at which acidity is reduced depends on the degree of fineness of the limestone. For quick action most limestone should pass through an 80 mesh sieve. In districts where the soils are naturally deficient in magnesia-bearing rock, as for example the Atlantic Coastal Plain, dolomitic limestone, a form of limestone containing large quantities of magnesium carbonate, is used to a greater extent than ordinary limestone.

Soil Reaction and Disease Organisms. In certain specific instances, the maintenance of a rather narrow pH range is necessary to control certain pests. For example, potatoes in many producing districts become infected with scab if grown in moderately to slightly acid soils; cabbage becomes infected with a slime mold if grown in very acid soil; and sweetpotatoes become infected with scurf if grown in slightly acid or slightly alkaline soil. To control diseases of these crops potato growers maintain a soil reaction of pH 5.2 to 5.5, since the scab organism does not thrive well in very acid soils. Cabbage growers maintain a slightly acid reaction and sweetpotato growers maintain a moderately acid reaction.

SULFATES

Plants absorb sulfur only in the form of sulfates, a highly oxidized form. Sulfur is necessary for the formation of certain proteins and for cell division.

Symptoms of Sulfur Deficiency. Investigations at the Ohio Experiment Station have shown that, with many flower crops, the veins of the leaves are lighter green than the remainder of the leaves. Note that this condition is exactly opposite to that for magnesium, manganese, and iron deficiency. The leaves of the upper part of the plant show the symptoms first. This indicates that sulfur is not transferred from one part of the plant to another.

Sources and Behavior in Soil. Natural supplies of sulfur are secured from organic matter in the soil and from the air. In both cases the activity of certain soil organisms is necessary to make sulfur available to plants. The sulfur in organic matter is in the form of protein-sulfur and is changed to hydrogen sulfide. This in turn is oxidized to sulfuric acid, which

combines with minerals to form a salt. This change from protein-sulfur to sulfate-sulfur is illustrated as follows:

$$\text{organic matter containing sulfur} \xrightarrow{\text{(reducing bacteria)}} H_2S + 2O_2 \xrightarrow{\text{(sulfur bacteria)}} H_2SO_4$$

$$H_2SO_4 + {}^{*}MOH \longrightarrow {}^{*}MSO_4 + H_2O$$

The sulfur in the atmosphere is in the form of elemental sulfur and is washed into the soil by rain. In the soil the sulfur is oxidized. This oxidized sulfur combines with water to form sulfuric acid which in the presence of a mineral forms a salt. In regions near certain industrial establishments the atmosphere contains relatively large quantities of sulfur. The change of elemental sulfur to sulfate-sulfur is illustrated as follows:

$$\underset{\text{(rain)}}{S + O_2} \longrightarrow SO_2 + O \longrightarrow SO_3 + H_2O \longrightarrow H_2SO_4 + M \longrightarrow {}^{*}MSO_4$$

Materials supplying sulfur are ordinary flowers of sulfur, ammonium sulfate, and gypsum. Flowers of sulfur is sometimes used to increase the acidity of the soil solution. Applications vary from 50 to 300 pounds per acre, depending on the soil reaction and the system of farming. The student will recall that ammonium-sulfate makes soils more acid also.

MATERIALS SUPPLYING MAGNESIUM

Plants absorb magnesium in the unoxidized state. Magnesium is absolutely essential for plant growth. *It is the center of the chlorophyll molecule.* Thus, its necessity for chlorophyll formation in the manufacture of foods is obvious. In addition, magnesium is necessary for cambium activity.

Symptoms of Magnesium Deficiency. The outstanding symptoms of magnesium deficiency is the loss of chlorophyll of the tissues between the veins of the leaves. In other words, the intervascular areas of the leaves change from dark green to light green and from light green to yellow while the veins remain green. This change from green to yellow starts at the margins and gradually proceeds to the center of the leaves. The symptoms usually appear first on the older leaves. In some plants the edges of the leaves turn brown and the tips of the branches die. In others, the chlorophyll disintegrates and necrotic areas develop. In all plants the tissues

*Minerals in soil solution.

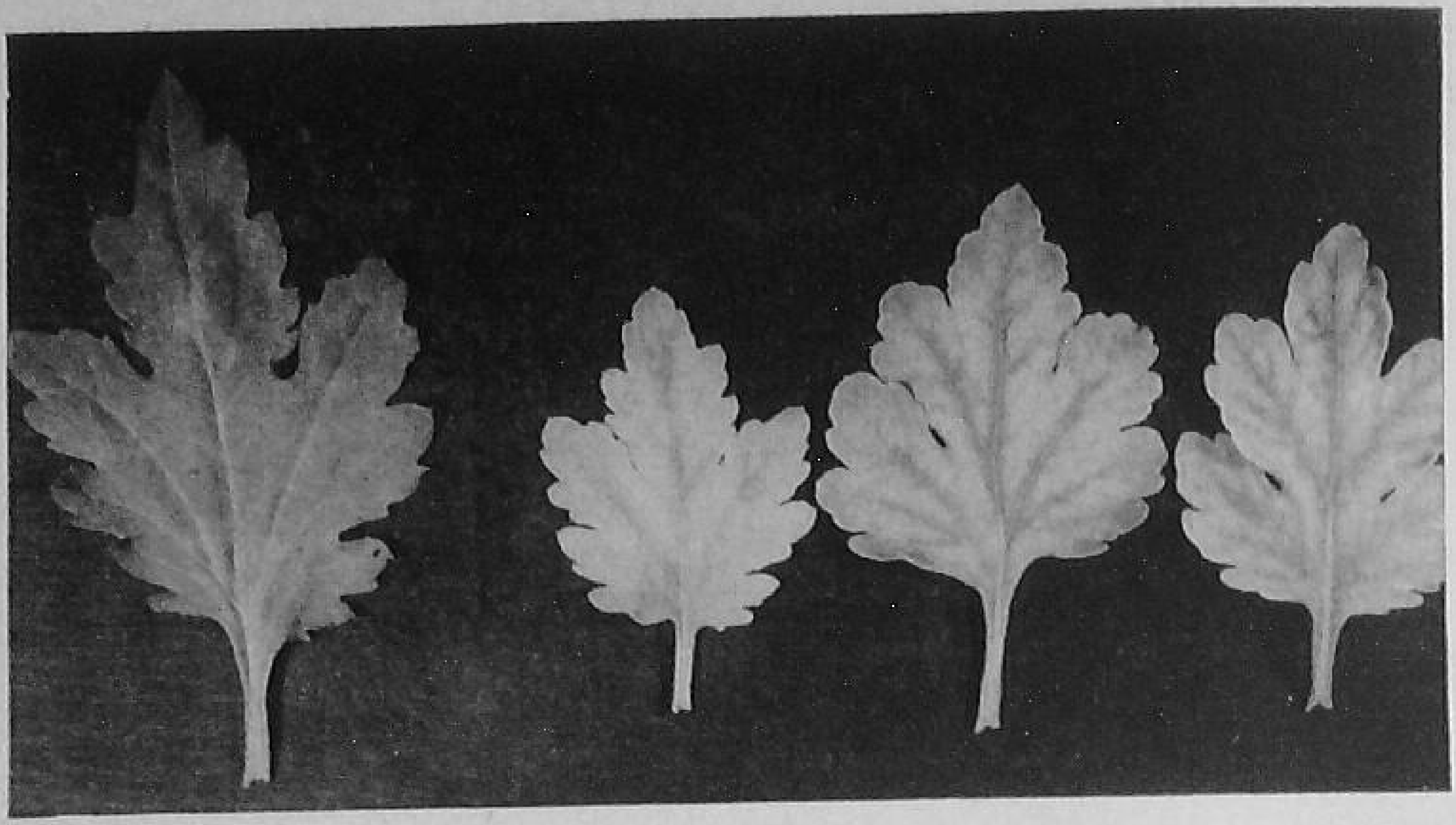

FIG. 30. Healthy and magnesium-deficient leaves of chrysanthemum. Leaf to left is from plant grown with a normal supply of magnesium; leaves to right are from a magnesium-deficient culture. (Courtesy, Alex Laurie, Ohio State University.)

are low in sugars and starch, the cells are thin-walled, and the strengthening tissue is poorly developed. Roots are small, few in number, and somewhat extensive. With flower crops blossoming is delayed and flower color is poor. Figure 30 shows healthy and deficient leaves of chrysanthemum. Note the chlorotic condition of the interveinal areas.

The soils of the United States vary greatly in natural magnesia. This can be determined by the amount of magnesia in the drainage water. Figure 31 shows the magnesia content of the drainage water of soils in various parts of the United States. Note the relatively low concentration, 1 to 3 ppm, in the drainage water of soils of the Atlantic Coastal Plain and of the extreme Northwest, and the high concentration, over 20 ppm, in the drainage water of the soils in the Middle West and West.

Principal factors influencing the amount of magnesium in the soil solution are: (1) The amount of magnesia in the soil-forming rocks and (2) the acidity of the soil. In regions where the magnesia content of the soil is low, the rock material from which the soil is formed is naturally low in magnesia, and the acidity of the soil is higher than in regions where the magnesium content of the soil is high. Within the regions of low magnesium content magnesium-deficiency symptoms first appeared in intensively cropped areas which are characterized by heavy precipitation and mild winter temperatures. Examples are the truck crop districts in the vicinity of Norfolk, Virginia and Charleston, South Carolina. In these districts

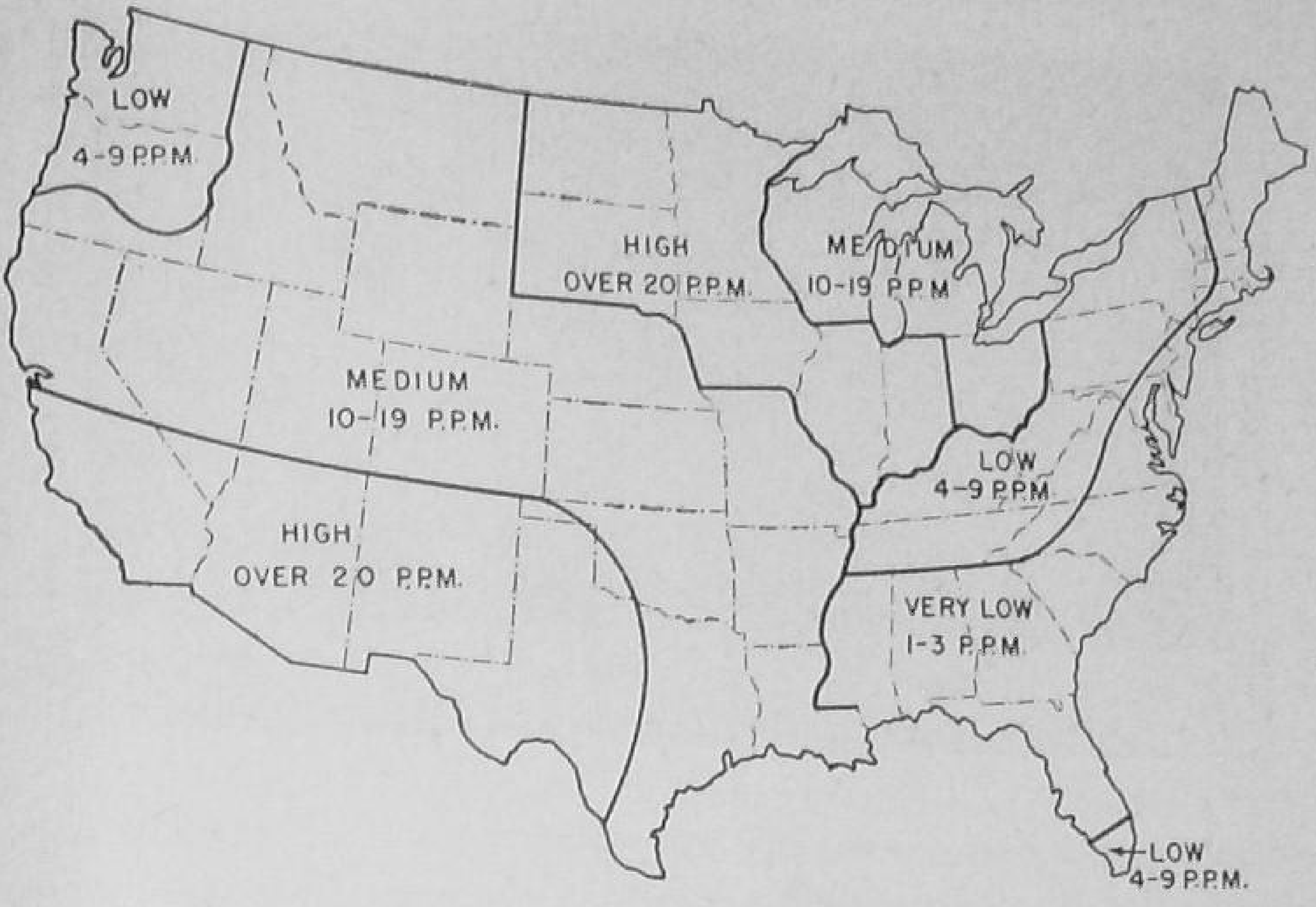

FIG. 31. Magnesia content of the drainage waters of the United States. (Redrawn from *Va. Truck Exp. Sta. Bul. 89*, 1935 and published with permission of S. B. Detwiler, Soil Conservation Service, U.S. Department of Agriculture.)

the growers apply magnesium in the fertilizer. Magnesium deficiency has occurred also in Aroostook County, Maine, the center of the greatest potato-growing district in the country.

Artificial Sources of Magnesium. Principal sources of magnesium are dolomitic limestone, magnesium sulfate (30.0 per cent MgO), and sulfate of potash-magnesia. Dolomitic limestone is a mixture of calcium and magnesium carbonate. Sulfate of potash-magnesia is a mixture of sulfate of potash and magnesium. Dolomitic limestone is less soluble than sulfate of potash-magnesia.

MATERIAL SUPPLYING IRON

The nutrient material used to supply iron is iron sulfate. Iron is necessary for the formation of chlorophyll. Like manganese, iron is believed to serve as a catalyst in chlorophyll formation.

Symptoms of Iron Deficiency. Investigations at the Ohio Experiment Station have shown that the intervascular area of young leaves of flowering plants turns light green and finally yellow. On some plants brown specks appear with the yellow areas. These brown or necrotic areas are usually larger than those due to manganese deficiency. Note the appearance of the blades of iron-deficient leaves of rose in Figure 32.

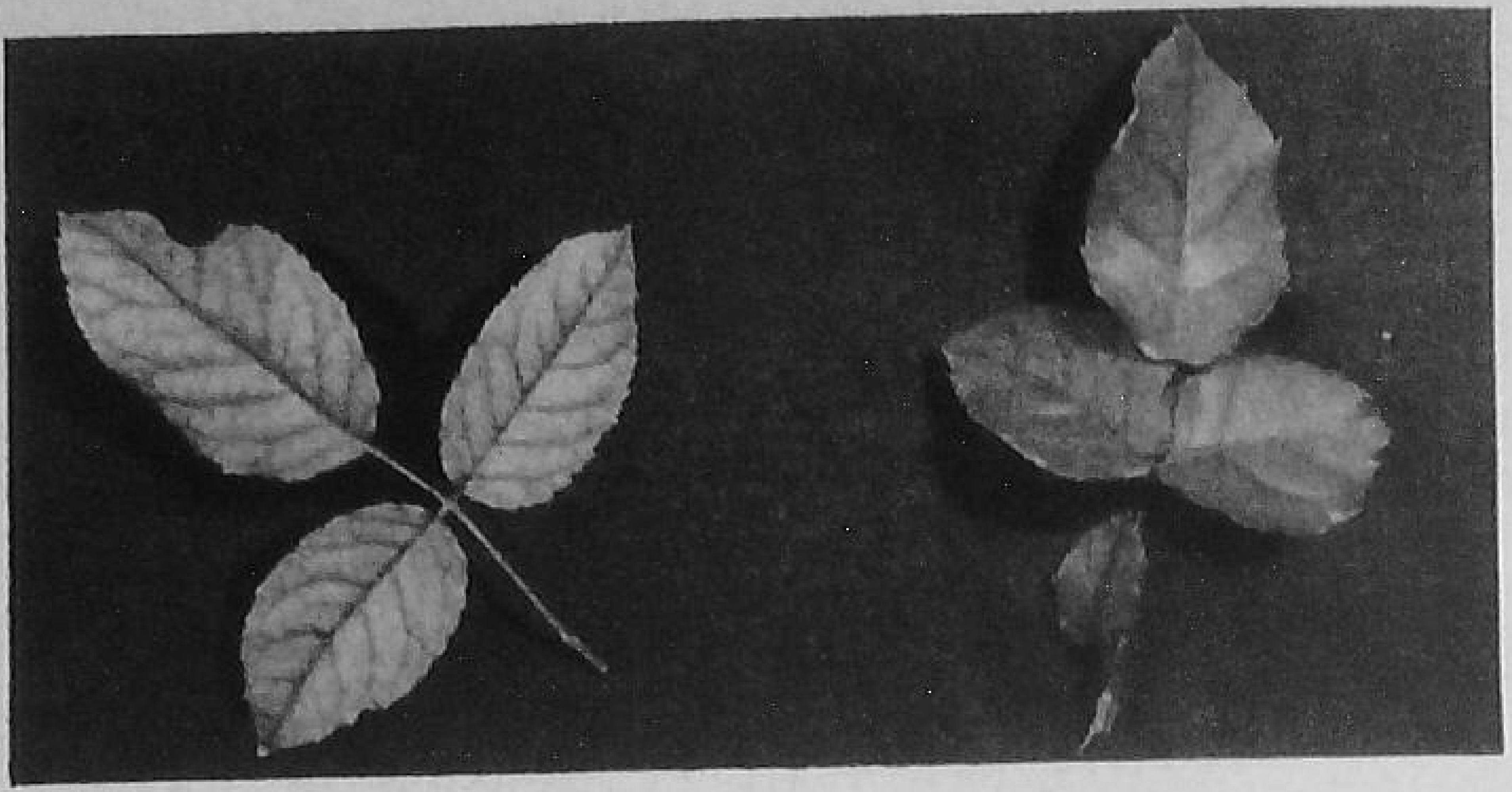

FIG. 32. Healthy and iron-deficient leaves of rose. (*Left*) Minus iron; (*right*) with iron. (Courtesy, Alex Laurie, Ohio State University.)

Sources and Behavior in Soil. Iron deficiency has occurred in only a few places in the United States and in other countries. It occurs usually in highly manganiferous or calciferous soils. Certain soils of the Hawaiian Islands are a notable example. These soils contain large quantities of manganese oxide and the iron in these soils is unavailable. Thus, iron applied to such soils is useless. However, tests at the Hawaiian Experiment Station have shown that the spraying of pineapple with ferrous sulfate has controlled chlorosis or iron deficiency. At present more than one-half of the pineapple fields are sprayed and the iron is absorbed through the tops.

MATERIALS SUPPLYING MANGANESE

The principal nutrient material used to supply manganese is manganese sulfate. *Manganese acts as a catalyst in chlorophyll formation.* Thus, manganese-deficient plants contain less sugars than corresponding non-deficient plants. Some recent work indicates that manganese is essential to respiration and nitrate reduction.

Symptoms of Manganese Deficiency. Symptoms of manganese deficiency are usually more difficult to distinguish than those of iron deficiency. However, investigations at the Ohio Experiment Station have shown that manganese deficiency of herbaceous flower crops can be distinguished from iron deficiency in three ways: (1) Manganese deficiency is usually not so severe as iron deficiency, (2) necrotic areas due to manganese deficiency are smaller and are located in the middle of the leaf, and (3) the veins remain green in manganese deficiency and the leaf has a netted appearance. Although manganese and iron have the same function in plants—the

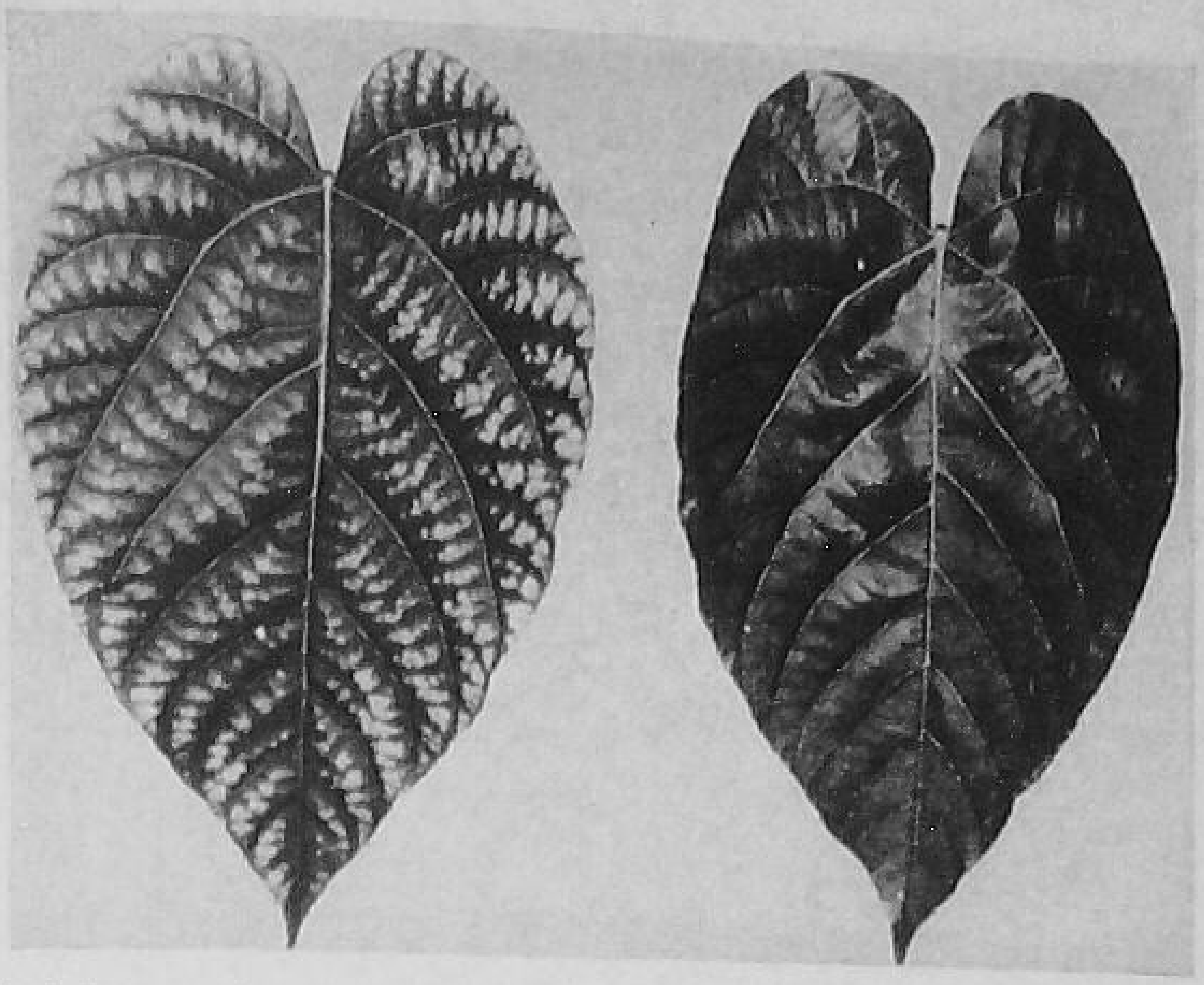

FIG. 33. Healthy and manganese-deficient leaves of tung. (Courtesy, R. D. Dickey, University of Florida.)

serving as catalysts in chlorophyll formation—tests have shown that manganese or iron cannot take the place of each other. Figure 33 shows healthy and manganese-deficient leaves of tung.

Sources and Behavior in Soil. The available manganese supply varies with soil type and acidity of the soil. For example, a sample of Ontario loam in New York was found to contain 0.094 per cent manganese oxide and a sample of Norfolk fine sandy loam in North Carolina contained 0.001 per cent. Usually available manganese is deficient in calcareous or slightly acid and alkaline soils. Tests in Florida have shown that manganese is almost insoluble in soils that have pH values from 6.2 to 8.0.

Where artificial applications are necessary, manganese is usually supplied in the form of manganese sulfate. This material is now used by vegetable crop growers in the vicinity of Charleston, South Carolina, by greenhouse growers in Ohio, and by citrus growers in southern Florida. Applications vary from 50 to 150 pounds per acre, depending on the manganese content of the soil, the acidity or alkalinity of the soil, and the system of cropping. In soils less than pH 5.0 manganese may become deficient due to leaching. In soils greater than pH 7.5 manganese may become insoluble and thus unavailable.

BORAX AND BORIC ACID

Recent investigations have shown that boron is essential for the growth of citrus, blueberries, grapes, lettuce, celery, cabbage, cauliflower, turnips,

garden peas, beans, and tomatoes. Undoubtedly, additional investigations will show that boron is essential for all crops. This element appears to be necessary for *the division of the meristem and the normal development of the conducting tissues.* Tests at the University of California have shown that the leaves of boron-deficient citrus trees accumulate large quantities of carbohydrates, possibly due to the scant development of the phloem tissue. There is some indication that boron is essential for normal respiration.

Symptoms of Boron Deficiency. A deficiency of boron has profound effects on the growth of plants. Non-development and death of terminal buds are characteristic of a lack of adequate amounts. Lateral buds may or may not develop, depending on the amount of boron present. The leaves on the top of the plants become thick and brittle and tend to roll in a half circle from the tip toward the base.

At the beginning of the twentieth century certain horticultural crops in many parts of the world became diseased because of the lack of boron. About 1930, growers of cauliflower in the Catskill Mountains of New York suffered severe losses. The internal flesh of the cauliflower became brown and bitter. In the northeastern region of the United States and in the maritime provinces of Canada and British Columbia and in sections of Ireland, Scotland, and Wales, the flesh of turnips and rutabagas became dark in color, light in weight, and woody in texture. In New York and New England apple trees became diseased with a condition known as "drought spot," "cork," or "internal cork." In Florida and Michigan a lack of boron caused a disease of celery known as "cracked stem." In all five crops applications of boron corrected the disease. With cauliflower the borax ($Na_2B_4O_7 . 10H_2O$) was applied at 5 pounds per acre, in trenches 4 inches to the side of the plants and 4 inches deep. With turnips and rutabagas the borax was applied either as a spray or as a side dressing at the rate of 10 to 15 pounds per acre. With apples holes were bored in the trunks and crystals were placed in the holes. With celery the borax was applied as a side dressing at the rate of 15 to 20 pounds per acre. In all cases the deficiency was corrected.

Since 1930 other horticultural crops have become sick because of a lack of boron. Examples are deciduous tree fruits in the Hood River Valley of Oregon and in Massachusetts; grapes in the Sand Hill section of South Carolina; spinach on Long Island, New York, and in Michigan; and cabbage in southern and eastern Maine and in central Mississippi. Thus boron deficiency is rather widespread. In fact, in 1939 a deficiency of boron

was reported in one or more crops in 24 states. Note the boron-deficient cabbage head in Figure 34.

Factors influencing boron deficiency are: (1) Soil type and (2) soil reaction. Soils most deficient in boron are old soils, sandy soils, mucks and peats, and soils derived from igneous rocks. Alkaline and neutral soils seem to be more deficient than moderately acid soils.

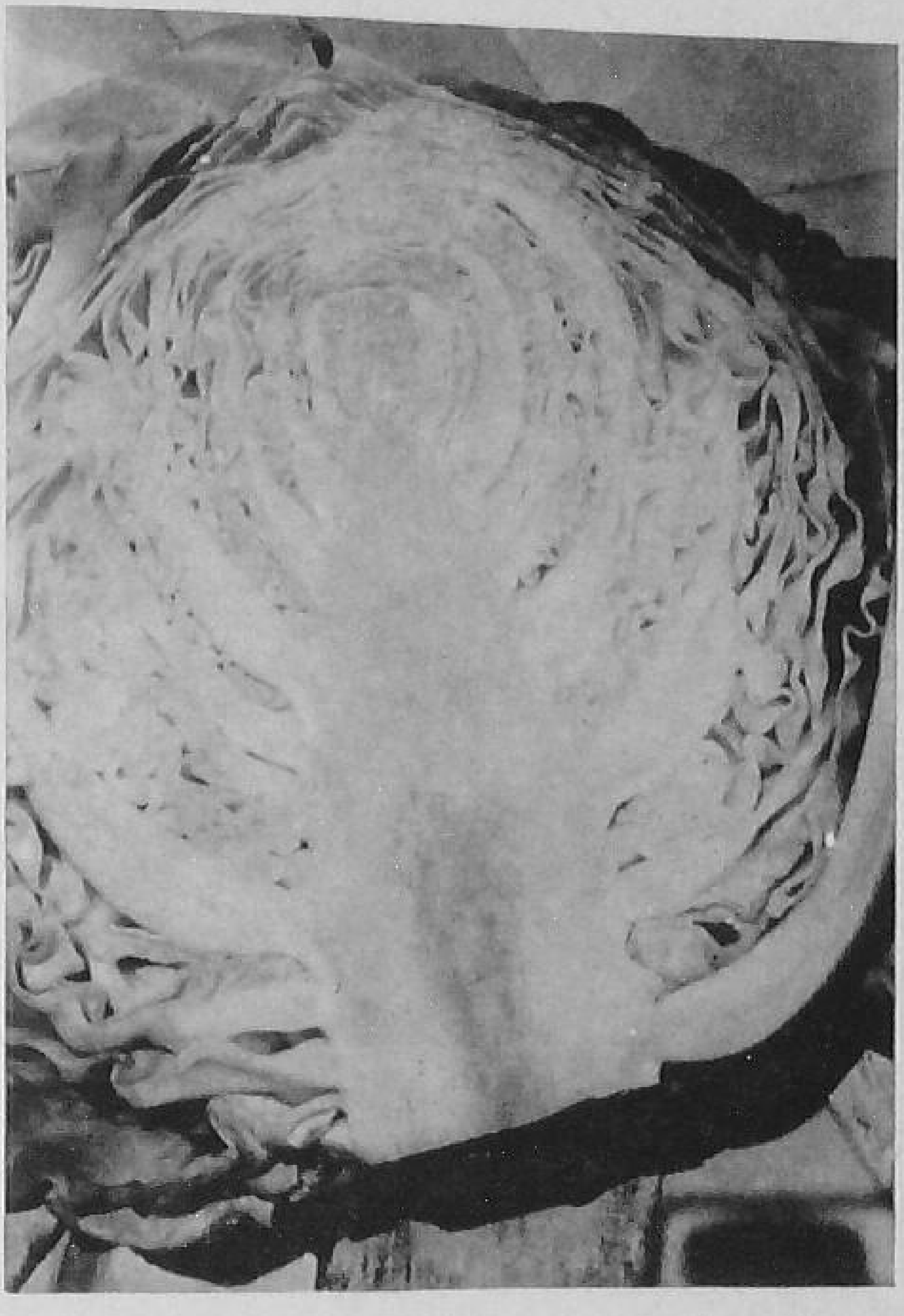

FIG. 34. A boron-deficient head of cabbage. (Courtesy, J. A. Campbell, Mississippi Agricultural Experiment Station.)

Plants require boron in very small concentration, usually from 0.1 to 1.0 ppm in the soil solution. If the concentration of the soil solution becomes greater than 1 ppm, toxic effects are likely to occur. The element is applied in the form of borax or boric acid. Although 2 pounds of boric acid supply approximately the same amount of boron as 3 pounds of borax, the latter is usually the more economical form. These materials may be applied (1) to the soil, (2) as a spray, or (3) as injections of boric acid into the trunk or limbs of trees. Of these methods the first is preferred. In general, when applications are necessary, fruit trees are given from 2 to 16 ounces of

borax per tree and herbaceous crops from 5 to 30 pounds of borax per acre.

ZINC SULFATE AND ZINC CHLORIDE

Zinc sulfate and zinc chloride supply zinc. This element is necessary for the growth and development of vegetables, cereals, buckwheat, corn, barley, and other crops. Scientists believe that zinc is necessary for chlorophyll formation and for photosynthesis.

FIG. 35. A zinc-deficient peach tree. (Courtesy, R. D. Dickey, University of Florida.)

Symptoms of Zinc Deficiency. In many regions of the country certain horticultural crops have shown symptoms of zinc deficiency. Examples are pecan and peach in the Southeast; walnut, citrus, and avocado in California; snap bean, citrus, and tung in Florida; and sweet cherry in Oregon. The identifying symptom is the development of tufts or rosettes of small leaves in deciduous tree fruits, the development of mottled leaves in citrus fruits, and the development of yellow leaves in walnuts. The twigs of affected trees usually die back each year, and the roots develop

normally since they apparently obtain sufficient zinc from the soil. Figure 35 shows a zinc-deficient peach tree.

Zinc deficiency is corrected by applications of zinc sulfate ($ZnSO_4 \cdot 7H_2O$), or zinc chloride ($ZnCl_2$). Applications may be made by spraying the tops, 2 to 5 pounds to 50 gallons of water; by placing a solution in holes bored in the trunks of trees; or by broadcasting crystals, 2.5 to 15.0 pounds per tree, on the surface of the soil. Tests have shown that zinc sulfate is fixed in direct proportion to the colloidal content of the soil and that zinc is unavailable in alkaline soils.

The student should remember that zinc may be present in soils growing plants showing zinc deficiency. For example, soils in certain parts of California contain within the root zone a total of approximately 3000 pounds of zinc per acre. However, investigations showed that this zinc was not available to the trees. Thus, the so-called fixing power of the soil is an important factor. The zinc content of the solution in ordinary soils varies from 1 to 10 ppm. The mid-point of this range seems to be the optimum concentration for plant growth.

COPPER SULFATE

Copper sulfate supplies copper. Recently, copper has been reported as an essential constituent of certain oxidizing systems in plants. In 1927 an unproductive saw grass peat in the Florida Everglades was given an application of 50 pounds of copper sulfate per acre. As a result, it produced excellent crops of lettuce, radishes, turnips, and tomatoes. Since that time tests conducted in various regions have shown that copper has a beneficial effect on the growth of many plants. This element has cured the "frenching" or spotting of leaves of citrus trees in California and Florida; it has increased the thickness of the scales and improved the color of onions grown on the muck soils of New York and Michigan; it has corrected chlorosis of deciduous fruits in South Africa; and it has increased the yields of potatoes, sweetpotatoes, onions, and snap beans in Delaware. On the muck soils of New York and Michigan which are given over to onion production, growers apply from 100 to 300 pounds of copper sulfate per acre.

MOLYBDENUM

Recent investigations at the California Experiment Station have shown that molybdenum is essential for the growth and development of Myrobalan seedlings of the plum. Plants grown in nutrient solutions lacking

molybdenum developed slowly and had short internodes and dwarfed leaves. The leaves developed light brown areas of dead tissue in the tips and margins. The symptoms of molybdenum deficiency were distinguishable from those caused by a lack of zinc or copper.

OTHER NUTRIENT ELEMENTS

Investigations have shown that aluminum, iodine, chlorine, and other elements are essential for the growth of certain plants. However, at present, these elements are not deficient in soils given over to the production of horticultural crops in the United States. Thus, artificial applications of nutrients supplying these elements are unnecessary.

Questions

1. Potassium-deficient plants store nitrate-nitrogen and carbohydrates. Explain.
2. What part of the leaf is first affected by potassium deficiency?
3. How would you distinguish potassium deficiency from nitrogen deficiency?
4. Name the commercial sources of potassium.
5. Calcium-deficient plants store carbohydrates. Explain.
6. What is acidity due to? Alkalinity?
7. Soil with a pH 3 is acid, with a pH 8 is alkaline, with a pH 7 is neutral. Explain.
8. Yields of most horticultural crops markedly decrease at reaction values below pH 5.0, at above pH 8.0. Give three reasons.
9. Name the three forms of lime and give their calcium equivalents.
10. How does dolomitic limestone differ from ordinary limestone?
11. Potatoes grown on soils with a pH 5.5 produce lesser quantities of scabby tubers than those grown on soils with a pH of 6.5. Explain.
12. In what state do plants absorb sulfur?
13. Outline the changes taking place from protein-sulfur to sulfate-sulfur and from sulfur to sulfate-sulfur.
14. What is the principal use of sulfur? How does sulfur make soils more acid?
15. State the role of magnesium in plant growth.
16. State the commercial sources of magnesium.
17. A potato sickness was overcome by applying 200 pounds of magnesium sulfate per acre at a cost of $3.50. Name the malady and give your reasons.
18. In what section of the country is magnesium naturally deficient in soils? Give two reasons.

19. Dolomitic limestone is used to a greater extent in the Southeast than ordinary limestone. Explain.
20. State the role of manganese and iron in plant growth.
21. Chlorotic plants are lower in sugars and carbohydrates and grow more slowly than healthy plants. Explain.
22. Pineapples sprayed with ferrous sulfate recover from chlorosis. Explain.
23. State the outstanding symptoms of boron deficiency.
24. How is boron deficiency corrected? State the substances which are used and how they are applied.
25. How is zinc deficiency corrected?
26. Although large quantities of zinc may be present in the soil, it is not always available. Explain.
27. How do applications of copper sulfate benefit onions growing on muck soils in New York, Michigan, and Florida?

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Part II

Principal Horticultural Practices

7

Propagation

Assignment 11

Modes of Reproduction. Among the higher plants there are two modes of reproduction: (1) Sexual or propagation by seed and (2) asexual or vegetative propagation. In sexual propagation the sperm and egg unite and form a new individual. In vegetative propagation a piece of stem or root, a vegetative bud or group of vegetative buds, or a storage structure are used to produce a new individual. Both types of reproduction are used in the production of economic plants. For example, most agronomic and vegetable crops are propagated by seed, most deciduous tree fruits, evergreen tree fruits, nut fruits, grapes, and small fruits* are propagated vegetatively, and certain flower crops are propagated by seed and others are propagated vegetatively.

PROPAGATION BY SEED

What Is a Seed? Essentially, a seed consists of a young plant or embryo with protecting and nourishing tissues. The protecting tissue is the seed coat. The nourishing tissues are endosperm or cotyledons. In well-developed, mature seed, these tissues are packed with stored food—starch, hemicellulose, reserve proteins, or fats. In general, the kind of food stored varies with the kind of plant. For example, sweet corn stores starch and dextrin; asparagus, onion, and date store hemicellulose; pea and bean store

*Small fruits include the brambleberries, currant, gooseberry, blueberry, cranberry, and strawberry.

reserve proteins; and pecan, walnut, lettuce, okra, the cucurbits,* and ornamental sunflowers store comparatively large quantities of fat.

The embryo is a minute plant. It consists of plumule, radicle, hypocotyl, epicotyl, and cotyledons. The plumule is the first growing point of the stem, and the radicle is the first growing point of the root. The hypocotyl and the epicotyl together constitute the first or original axis of the plant. When the seed of certain plants germinate, such as bean, onion, and the cucurbits, the hypocotyl elongates. In this way it pulls the cotyledons and plumule out of the ground. On the other hand, when the seed of other plants germinate, such as garden pea and sweet corn, the hypocotyl does not elongate, the cotyledons remain in the soil and the epicotyl elongates. In this way it pushes the plumule through the surface of the soil.

Seedage

Before the grower plants the seed it must be produced, cured, harvested, stored, marketed, and frequently treated. Practices having to do with the growing, harvesting, curing, storing, marketing, buying, treating, and planting of seed are collectively called seedage.

The Garden Seed Business

Although many florists and vegetable growers save their own seed, by far the greater majority of seed planted in the United States is produced by a relatively small number of seed houses. This raising of seed for sale is a highly specialized and technical business. Factors pertaining to the climate, the plant, and the grower are involved.

Climatic Factors. Seed growers, in common with the growers of other products, should receive profitable returns for the growing of seed. With most seed crops, profitable returns depend primarily on securing large yields of high quality, well-cured seed combined with low costs of production. Not all climates are suited to the production of large yields of high quality, well-cured seed. In general, the dry climate of the irrigated districts of western United States is far more favorable than the humid climate of eastern United States. The less rainfall and the long periods of sunshine combined with applications of irrigation water in the western United States promote a rapid rate of photosynthesis, large yields, proper ripening, and curing. Conversely, the more frequent and abundant rainfall of the humid regions favors the development of certain foliage diseases

*The cucurbits include cucumber, cantaloupe, pumpkin, squash, and watermelon.

and frequently retards proper ripening and curing. Note the seed-producing districts of the crops listed in Table 15.

Table 15

PRINCIPAL SEED-PRODUCING DISTRICTS OF CERTAIN CROPS

Crop	*Seed-producing Districts*
garden pea	high areas of Washington, Montana, Idaho, and Wyoming
cabbage, spinach, beet	Puget Sound and Vancouver Island
lettuce	Santa Clara Valley and Delta of California
cucumber, cantaloupe	Colorado River Valley
snap bean	Idaho, Montana, California
many flowering plants	California

Plant Factors. The principal plant factor is the mode of pollination. As previously stated, with sexually propagated crops a self-pollinated plant is one which is pollinated with its own pollen (intra-plant pollination), whereas a cross-pollinated plant is one which is pollinated with the pollen of some other plant (inter-plant pollination). Because of the greater possibility of introducing new characters in cross-pollination, cross-pollinated plants possess a greater diversity of characters than self-pollinated plants. They, therefore, require more care in the maintenance of a specific genetic constitution. To prevent contamination by undesirable pollen, seed crops must be properly isolated. Thus, with cross-pollinated crops the seedsman must consider time of shedding of pollen and time of receptivity of the pistil of adjoining strains and varieties. If the crops are wind-pollinated, he must consider the direction of the prevailing winds, or if the crop is insect-pollinated, he must consider the activity and crop preferences of the pollinating insect. Examples of strains and varieties of crops which cross readily are cabbage, stocks, candytuft, onion, alyssum, and the cucurbits. Examples of crops which are largely self-pollinated are garden pea, snap bean, tomato, sweet pea, and snapdragon.

Grower Requirements. The production of seed also requires close attention to details, keen observation of the behavior of the plants, and a working knowledge of the principles of genetics and plant breeding. The successful seed grower has keen powers of observation; he is skillful in judging and in selecting desirable types; and he has a knowledge of the technique

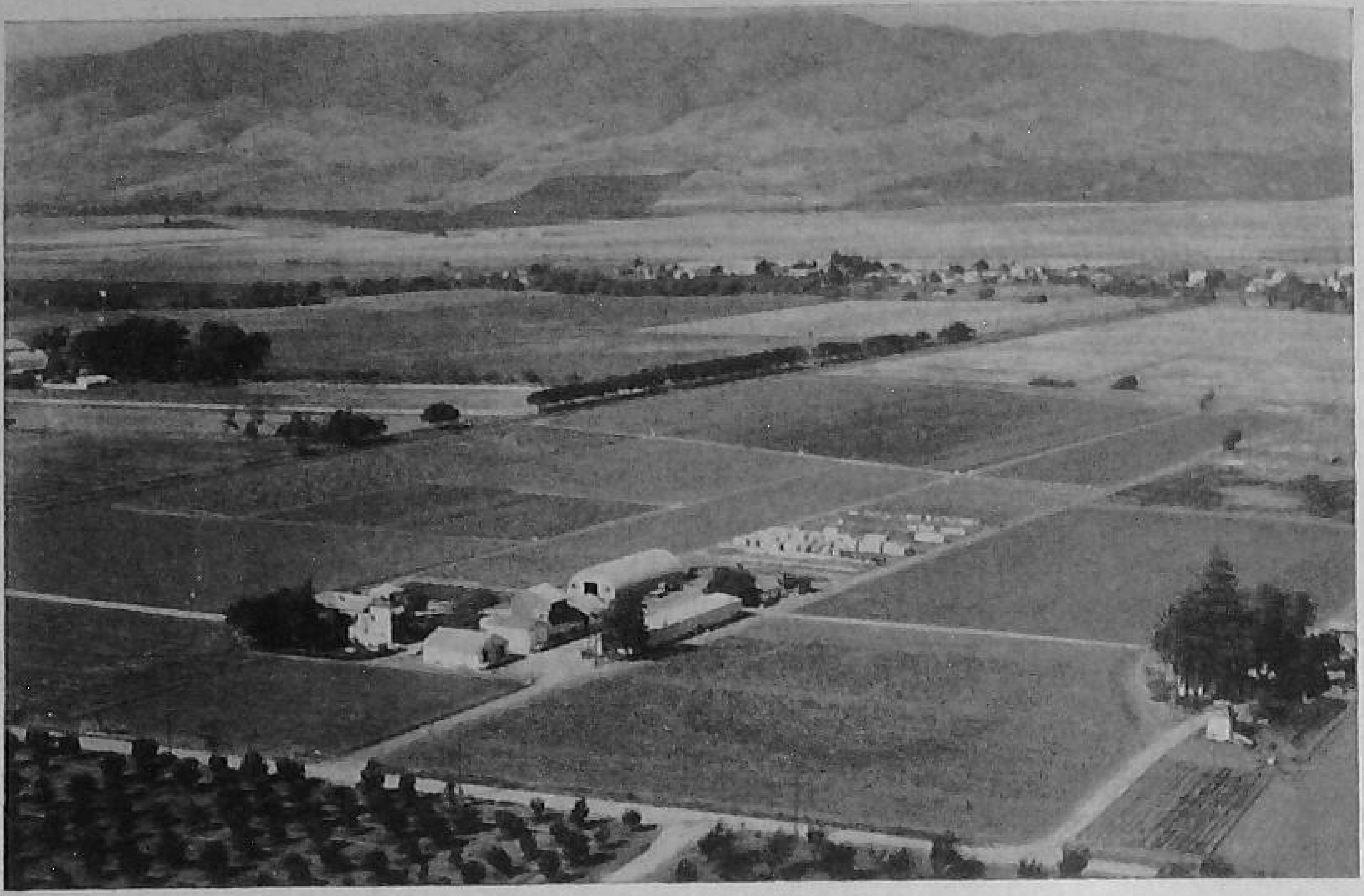


Fig. 36. A modern seed breeding station given over to the maintenance of standard varieties and to the development of new and improved types. (Courtesy, Associated Seed Growers Inc., New Haven, Connecticut.)

of pollination and isolation. Not all growers are temperamentally suited to this type of enterprise. Figure 36 shows a modern seed breeding station in the Santa Clara district of California.

Home Saving of Seed

Many home gardeners, many market gardeners, greenhouse growers, and florists frequently save seed of superior plants. In fact, certain varieties of vegetable and flower crops have been developed by this method. Many of these varieties carry place names which usually indicate that they have been developed in a certain locality. Examples are: Grand Rapids Forcing lettuce developed at Grand Rapids, Michigan; Red Wethersfield onion developed near Wethersfield, Massachusetts; and Los Angeles China aster developed at Los Angeles, California.

Advantages of home saving of seed are as follows: (1) The grower can practice rigid selection and (2) the plant selected is likely to be adapted to the local environment. A disadvantage is that interstrain and inter-varietal pollination of cross-pollinated crops is likely to take place. Wind, bees, or other pollinating insects may cause bad mixtures. Since the average grower does not possess the knowledge and skill necessary for successful seed production, he generally buys his seed.

Buying of Seed

Seed differs in productivity and adaptability. For any given region some strains of the same variety are adaptable and thus profitable. Other strains are non-adaptable and thus unprofitable. For example, in 1935, tests at the Truck Crop Station at Charleston, South Carolina, showed that four different strains of Drumhead Savoy cabbage differed markedly in plant performance. One strain produced a high percentage of offtype, unmarketable heads and another strain produced a high percentage of seeders.* Several years ago a similar test at Cornell University showed that two strains of the Copenhagen Market cabbage differed markedly in earliness of maturity of the heads. Since earliness of maturity is particularly important in the growing of this type of cabbage in New York and adjacent states, the earlier strain was more profitable than the later strain. Many other examples could be cited. In other words, there are marked differences in the behavior of strains within varieties, and a certain strain or variety may be adapted to one region of the country and unadapted to another. To determine the differences in behavior of sexually propagated crops, experiment station and extension workers, and breeders of seed companies conduct variety trials. Thus, the adaptation of new strains and varieties is determined for any given environment.

Since seeds for sale are produced in regions favorable for high yields, reliability of the seed house is more important than its locality. For example, as previously stated, most all lettuce seed is raised in California. Consequently, all growers of lettuce, whether in Florida, North Carolina, or New York will use seed which has been raised in California. In fact, the seed used by growers in the many lettuce-producing districts may have been raised on the same farm or at least in the same locality. In other words, lettuce seed is produced and cured in practically the same environment. If there are differences in the behavior of the seed, it is due primarily to differences in their inherent characteristics. Since the price of seed is a small item in the cost of production, the grower obtains seed of strains and varieties which have been bred to produce high yields in the local environment.

Storing of Seed

The principal process concerned is respiration. The stored food combines with water to form soluble food which in turn combines with oxygen to

*A seeder is a cabbage plant which produces seed stalks instead of a head.

form carbon dioxide and water with the liberation of heat and other forms of energy. Note the equation:

$$\text{Stored food} + \text{water} \longrightarrow \text{soluble food} + O_2 \xrightarrow{\text{(Enzymes)}} CO_2 + H_2O + \text{heat and other forms of energy}$$

While seeds are stored this process should proceed very slowly. Principal environmental factors which govern the rate of respiration and thus the longevity of stored seed are: (1) The amount of water in the air and (2) the temperature of the air. With other factors favorable, increases in the water supply of the air or increases in temperature will increase the rate of respiration. Of these two factors, the water supply is the more effective in controlling the respiration of seeds in storage. A study of the equation will show that water is necessary to change the stored food which is insoluble to soluble forms. Thus, if the rate of change is low the amount of soluble food formed will be low, and the rate of respiration will be low, even in the presence of a high temperature. Many investigations have shown that the relative water content of the air is the main factor in seed storage. For example, studies of the deterioration of ten kinds of vegetable

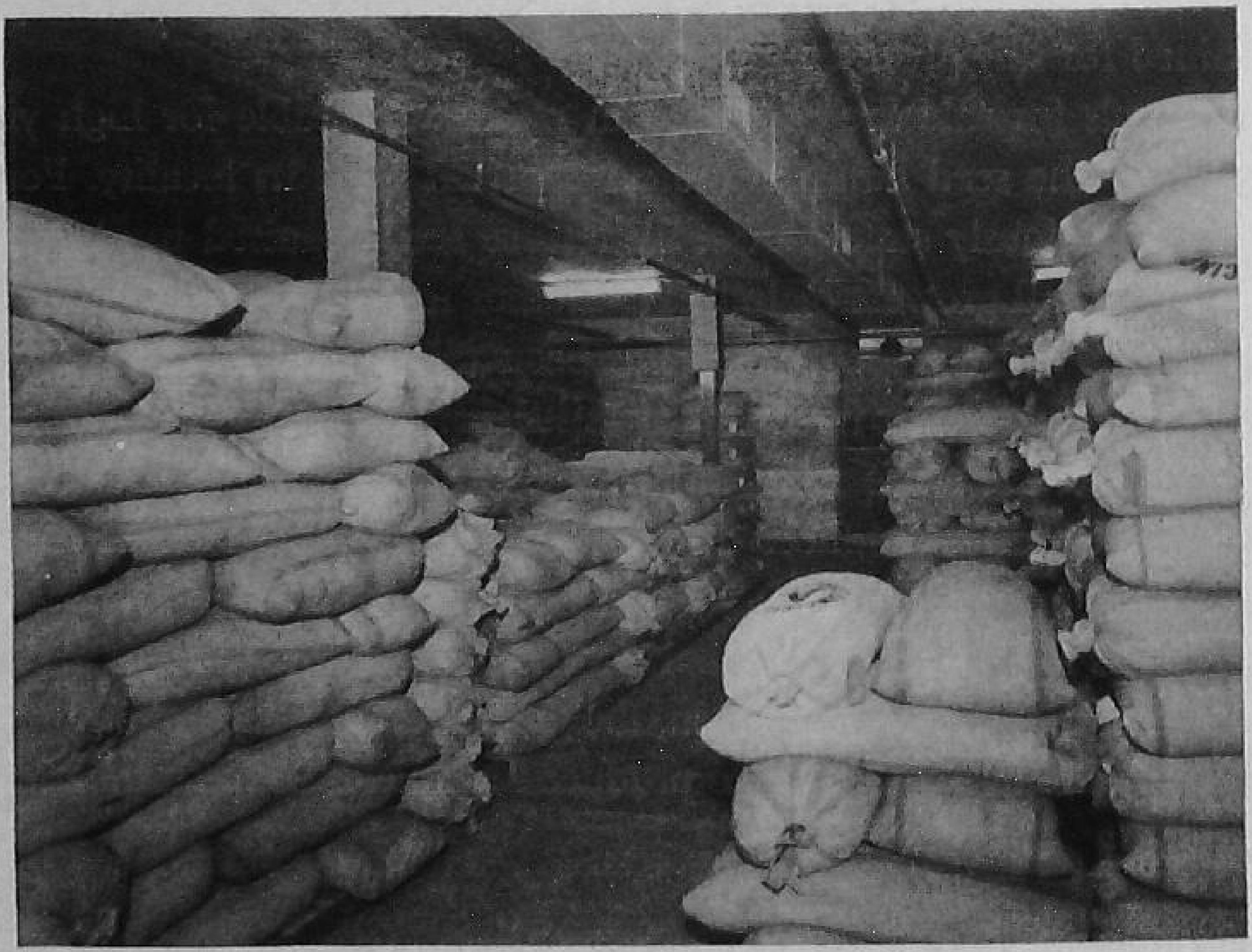


FIG. 37. Interior view of room of seed storage house. This room is equipped with air cooling and air drying machinery in order to maintain favorable temperatures and relative humidities for long storage life of seed. (Courtesy, Ferry-Morse Seed Co., Detroit, Michigan.)

seed were made at the Plant Industry Station, Beltsville, Maryland, in 1940. The results showed that the mean moisture content of the seed was positively associated with the relative humidity of the air, and that seed with a high moisture content deteriorated more rapidly than seed with a low moisture content. A relative humidity of 40 to 50 per cent or less was favorable for a long storage life. Thus, in warm-humid regions, such as the Gulf Coast of the United States, the percentage of germination and vitality of seed may decrease seriously during the period between shipment of the fresh seed to the local dealer by the producer and the time of sowing by the grower. To retard deterioration in warm-humid climates, seed are stored in waterproof containers or in rooms with dry air. Figure 37 shows a room of a garden seed storage house at Memphis, Tennessee.

Some plants develop seed which retains its viability longer than other plants. In fact, vegetable and flower crop seed can be placed into three groups: (1) Kinds dependable for a short period, (1 or 2 growing seasons), (2) kinds dependable for a moderately long period, (2 or 3 growing seasons), and (3) kinds dependable for a long period, (3 or 4 growing seasons). See Table 16.

Table 16

LONGEVITY OF VEGETABLE AND FLOWER SEED

Dependable for:		
1 or 2 Seasons	*2 or 3 Seasons*	*3 or 4 Seasons*
onion, sweet corn, celery, parsnip, primrose, lantana, viola, verbena	asparagus, pea, bean, cabbage, lettuce, spinach, okra, petunia, salvia	cucurbits, dahlia, dianthus, lupine, carnation, amaranthus

TESTING OF SEED

The prime object of testing seed is to determine the rate of planting. Since thinning due to excessive seed or poor stands due to non-viable seed increases the cost of production, growers always desire a full stand of plants. In general, the rate of planting is more accurately determined by the viability of the seed than by its percentage of germination. Viability refers to the rate of growth of the seedling plant. Two lots of seed may have the same percentage of germination but the sprouts of one lot may have made the greater growth, and hence they will be more vigorous than those of the other lot. Obviously, the lot with the more vigorous sprouts has the greater viability. Two general methods are available for the testing

of seed: (1) The planting of seed in soil or sand and (2) the germination of seed between folds of blotting paper, cotton flannel, or burlap. Each method has advantages and disadvantages. The United States Department of Agriculture and many states have laboratories for the testing of seed of horticultural and agronomic crops.

Treating of Seed

The prime object of treating seed is to protect seedling plants from certain parasites.* Many plant disease organisms are borne on the seed; many are present in the soil. These parasites are divided into two groups: (1) Those which attack seeds of most crops and (2) those which are specific to certain crops only.

Parasites which attack seeds of most crops are present in many soils. They usually attack the plants in the seedling stage, particularly when they are growing in greenhouses, hotbeds, and cold frames. Because of the high humidity and the warm temperatures frequently maintained in these structures, these parasites produce a condition which is characterized by growers as "damping off." This disease is caused by a group of fungi which thrive best in warm-humid conditions. Usually the stem of the young seedling is attacked just before or just after it appears above the surface of the soil. Many chemicals have been tested to control this disease. Examples are: Arasan, Semesan, Semesan Bel, and red copper oxide. In general, these chemicals are applied in the dust form, and directions for their application are usually printed on the container.

Parasites which attack seeds of specific crops are fungi and bacteria. As in the case of "damping off," scientists have developed methods of controlling these pests. The chemical most frequently used is mercuric chloride, popularly known as corrosive sublimate. The usual concentration is 1 part of the chemical to 1000 parts of water (by weight) and the period of soaking varies from 5 to 20 minutes depending on the kind of seed used.

Germination of Seed

Germination is essentially a quickening of the growth of the embryo or seedling plant. Before germination begins the young plant is relatively small and dormant. As germination proceeds the growing points of the radicle and plumule divide rather rapidly. Usually the radicle emerges

*A parasite is an organism which cannot make its own foods and feeds on living tissues.

from the seed coat first and proceeds downward and develops into the root system. The plumule proceeds upward and develops into the shoot system. The fundamental process concerned in germination is respiration. The stored insoluble foods are changed to soluble foods. This soluble food is translocated to the rapidly dividing growing points where it is utilized for the making of new cells and for the liberation of energy. *Germination, therefore, is entirely a food utilization process.* It is not complete until the seedling has begun to make and utilize its own food.

Processes which are necessary to make the food available at the growing points are: (1) Absorption of water, (2) secretion of enzymes, (3) hydrolysis of stored food, and (4) translocation of soluble food to the growing points. These processes are either wholly or in part influenced by the following factors: (1) Food reserves, (2) supply of water, (3) supply of oxygen, and (4) temperature.

Food Reserves. The main function of the reserve food is to nourish the young seedling until it can make its own food. These foods are starch, hemicellulose, proteins, or fats. If the food supply is low, the young seedling is likely to become weak and stunted. In extreme cases it even may not receive sufficient energy to push its radicle very far into the soil or its plumule above the surface of the soil. Relatively small, shriveled, immature seeds are usually low in food reserves. These seeds usually are separated from plump non-shriveled seed in the fanning process.

The Water Supply. An adequate and continuous supply of water is necessary. Functions of water in germination are: (1) To soften the seed coat, (2) to combine with stored food to form soluble food, (3) to serve as a transportation medium of soluble foods to the growing points, and (4) to enlarge the growing cells. Seeds germinate slowly in comparatively dry soil. Quite often the use of special devices is necessary to facilitate the germination of small seed which, of necessity, must be planted shallowly. For example, celery and lettuce seed are firmed into the surface of finely pulverized, carefully leveled soil, and burlap is spread on the surface to prevent washing of the seed. Recently, glass wool wick was tested for its ability to supply water for the germination of certain flower crop seed in flats. The plant wick is in sections 12 inches long and one end is placed through a hole in the center of the bottom of a flat and flared out like the spokes of a wheel. The flat is filled with a sterilized mixture consisting of one-third sand and two-thirds soil. Seed is planted in rows and watered thoroughly. The flat is then propped up in the bench with the wick in a container of water, and covered with a pane of glass for 1 or 2 days. With

this method only one watering is necessary. Excellent results have been secured with delphinium, snapdragon, stock, cineraria, begonia, petunia, and calceolaria.

The Oxygen Supply. An adequate and continuous supply of oxygen is necessary also. Functions of oxygen in germination are: (1) To combine with sugars to form carbon dioxide and water and (2) to liberate energy. This need for oxygen explains why soil should be moist but not wet; why the germination media should be loose and friable; why, in most cases, better results are obtained in sand or sandy loams than in clays; and why certain seeds are planted shallowly.

Temperature. Temperature markedly influences all germination processes. In general, increases in temperature, especially within the optimum range for growth, increase the rate of water absorption, the rate of translocation of soluble food, and the rate of cell division. Since germination should proceed rapidly, fairly high temperatures, usually those within the upper half of the optimum range for the growth of any given plant, should be maintained.

Light. Investigations have shown that light stimulates the germination of seeds of some horticultural crops and reduces the germination of others. For example, the germination of freshly harvested seed of lettuce, celery, and primrose is markedly increased by exposure to weak light. On the other hand, the germination of onion, garlic, and chive seed is retarded by light. The germination of many seeds is not influenced by light. In other words, the seeds germinate equally well in light and in darkness.

Rest Period of Seeds. Although the seed of most vegetable and flower crops will germinate immediately after they are harvested, the seed of some crops require a rest or after-ripening period before they will germinate. In other words, certain physiologic and biochemical changes must take place before the young plant will grow. These changes may be related to the secretion of enzymes, the absorption of water, or to some other process. Examples of seeds which require a rest period are: apple, pear, peach, plum, pecan, some of the alpines, and many of the woody ornamental shrubs.

Planting of Seed

Seeds are planted by hand or by machine. Seed planted in containers (pots, pans, flats) and in greenhouse beds or benches are usually planted by hand. Seed planted in gardens, fields, and orchards are usually planted by machine. Machines which plant seed are called drills. Seed drills may

be operated by hand, horsepower, or by tractor. In general, they plant seed at the required depth, at a uniform rate, and firm the soil around the seed. Some drills are equipped to place commercial fertilizer at varying rates on the side of the seed. Note the six-row seed drill in Figure 38.

The depth of planting depends on: (1) Type of germination, (2) moisture content of the soil, and (3) soil type. Seedlings which pull their cotyledons out of the soil require more shallow planting than seedlings, the cotyledons of which stay in the soil. For example, although seed of the bean is large, because the hypocotyl pulls the cotyledons out of the ground, it should be planted shallowly. Note the differences in behavior of the hypocotyl and epicotyl of certain plants in Figure 39. In general, the drier the soil the greater is the depth of planting. For this reason seeds usually are planted at a greater depth in summer than in the fall, winter, and early spring. Seeds usually are planted deeper in light soils than in heavy soils. This is due primarily to the differences in moisture content and oxygen supply between the two types.

Time of planting seed in the garden and field depends largely on the temperature requirements of the crop and temperature of the locality. Since warm-season crops cannot withstand comparatively low tempera-

FIG. 38. A tractor-drawn, six-row seed drill in operation. Note the well-prepared seed bed and row marker on each side of the machine. (Courtesy, International Harvester Co., Chicago, Illinois.)

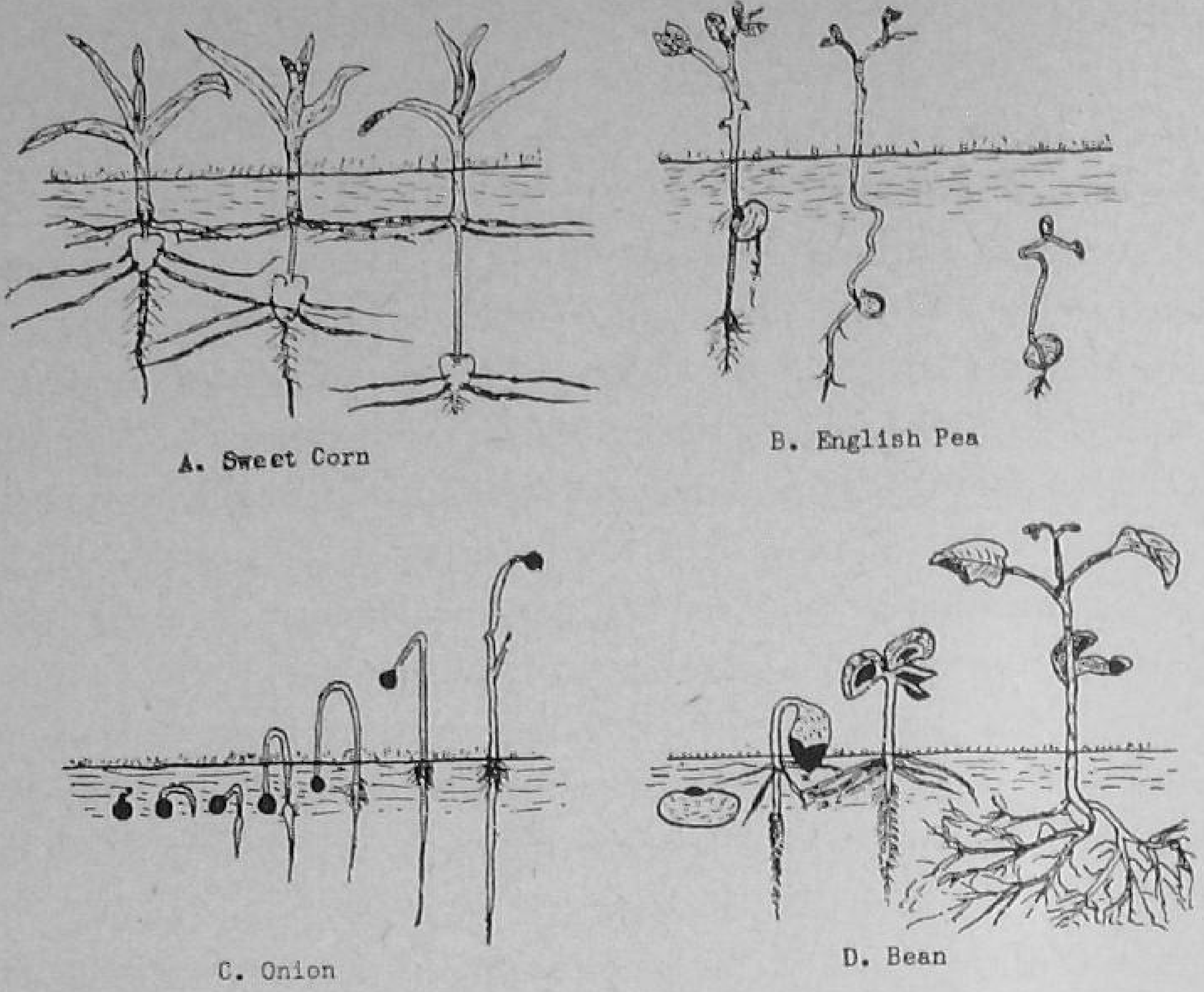


FIG. 39. Relation of type of germination to depth of planting. (A and B) Cotyledons remain in the soil. (C and D) Cotyledons "lifted" above the soil.

tures, they are not planted until the soil is sufficiently warm for, at least, moderately rapid germination. Consequently, the time of planting seed of these crops is determined largely by the average date of the last killing frost in the spring and of the first killing frost in the fall. On the other hand, since many cool-season crops can withstand temperatures as low as 20° F., seed of these crops may be planted before the last killing frost in the spring and after the first killing frost in the fall. This is true especially in regions characterized by mild winter temperatures.

Pelleting of Seed. Pelleting consists of coating an individual seed with a finely divided clay called montmorillonite. Each pellet is round and uniform in size regardless of the size and shape of the individual seed. On a theoretical basis, pelleting permits uniform planting, eliminates thinning, and presents the possibility of incorporating chemicals (nutrients, hormones, and fungicides) with the clay. However, more research is necessary to eliminate the placing of two or three seeds in a single pellet and to facilitate a more uniform rate of germination. Seeds which have been tested are: sugar beet, garden beet, lettuce, cabbage, cauliflower, broccoli, carrot, tomato, and petunia. Figure 40 shows essential steps in the pelleting of beet seed.

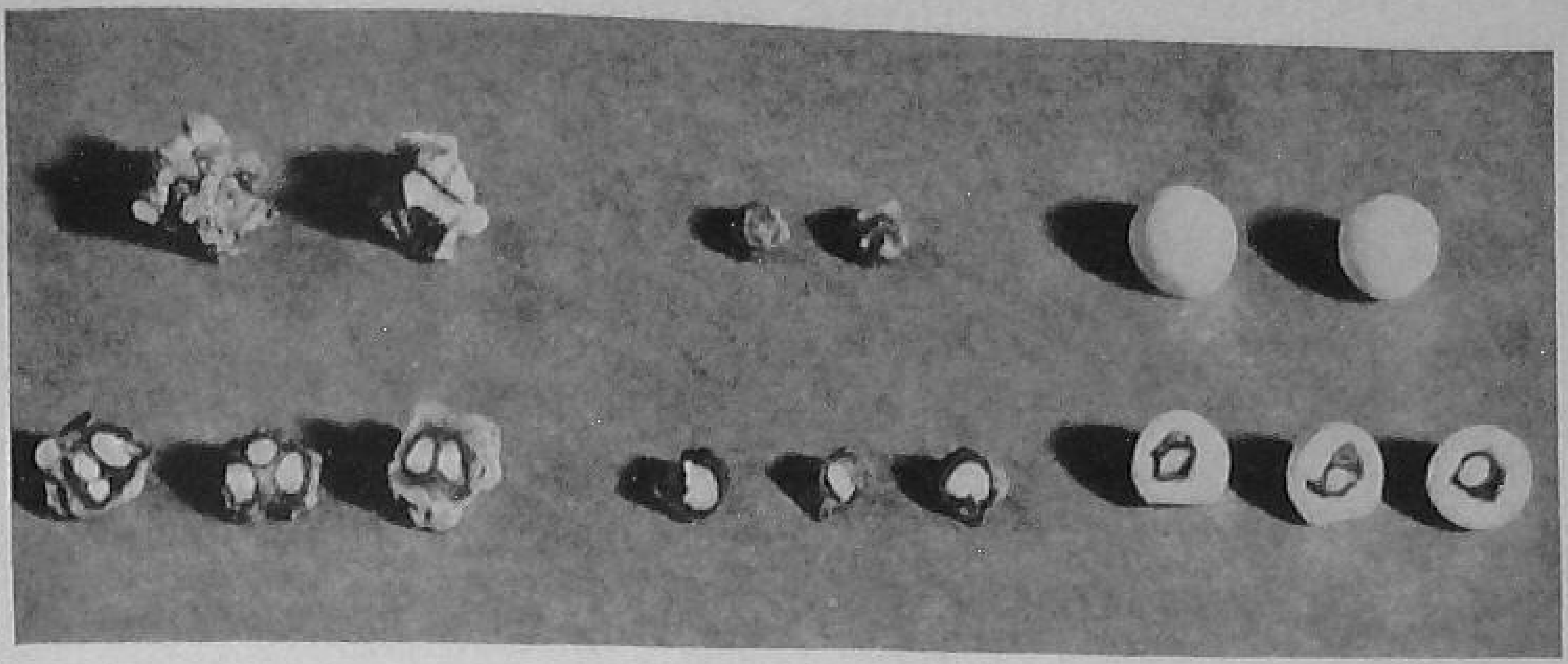


FIG. 40. The pelleting of beet seed. (*Upper row*) Whole fruits, separated seed, and pelleted seed. (*Lower row*) Sections of whole fruit, separated seed, and pelleted seed. (Courtesy, Processed Seeds, Inc., Midland, Michigan.)

Thinning. In general, thinning is a selective process. That is, the weakest seedlings are removed. In this way a comparatively large percentage of vigorous plants remain. With most crops there is a close relation of vigor of the seedling to yield.

Questions

1. What is a seed?
2. In general, most vegetable and flower crop seed are raised in regions favorable for high yields. Explain.
3. Given two seedsmen, A and B. Seedsman A is located in your home town; seedsman B is located 200 miles away. Seedsman A buys the cheapest seed; seedsman B buys the best seed (usually the most expensive). From which seedsman would you buy your seed? Give reasons.
4. Given two seedsmen, A and B. Both seedsmen buy the best seed. Seedsman A is located in your own town; seedsman B is located 500 miles away. From which seedsman would you buy your seed? Give reasons.
5. How would you obtain information on the reliability of seed houses in your community?
6. In saving of seed the behavior of the entire plant and not the characteristics of a single fruit should be made the basis for selection. Explain.
7. Your mother wishes to save seed from crops raised in the home garden. State briefly the difficulties involved. List the type of crops she may work with first. Give your reasons.
8. Seeds while stored gradually decrease in dry weight. Explain.
9. For the storage of vegetable and flower crop seed, dryness of the environment is more important than coolness. Explain.
10. Seed stored in the arid West retains its vitality longer than seed stored in the humid East. Explain.

11. How would you store small lots of garden seed in a warm-humid climate?
12. Your mother wishes to store a small quantity of okra or watermelon seed. Outline a practical and effective method.
13. Germinating seeds quickly decrease in dry weight. Explain.
14. Name the processes going on in seeds during germination. State the principal environmental factors conditioning these processes.
15. The germination of seed is primarily a utilization process. Explain.
16. In general, open, porous, relatively infertile, well-drained soils facilitate germination to a greater extent than closed, non-porous, relatively fertile soils. Explain.
17. State two advantages and two disadvantages of sand and clay as germinating media.
18. Seed of cool-season flower and vegetable crops can be planted earlier in the spring than seed of warm-season crops. Explain.
19. Firming of the soil immediately after planting the seed facilitates germination. Explain.
20. Excessive quantities of water, clay soil, or deep planting retard or entirely prevent seed germination. Explain.
21. Tomato and cabbage seed are usually planted in rows beneath the surface of the soil, and celery and lobelia seed are usually scattered on and gently pressed into the surface of the soil. Explain.
22. Seed flats or seed pans should always be set level in the hotbed or greenhouse. Explain.
23. What is pelleting?

Assignment 12

VEGETATIVE PROPAGATION

As stated before, vegetative propagation consists of using vegetative structures—stems, leaves, or roots. These structures contain buds which grow and develop into new individuals. This method of propagation is essential for the raising of many economic crops. Examples are: the deciduous fruit crops, evergreen fruit crops, nut fruits, many flowering and ornamental crops, and certain vegetable crops.

Reasons for Vegetative Propagation. The prime reason for vegetative propagation is that *many crops, if propagated by seed, would not resemble the parents which produced the seed.* For example, if seed from a Winesap,

Delicious, or Baldwin apple is planted, the trees which would develop from this seed would bear apples quite unlike those of the parent. They would vary greatly in size, shape, color, quality, season of maturity, keeping ability, chemical composition, and other characteristics. On the other hand, if a bud from a Winesap, Delicious, or Baldwin tree is taken and grafted on a piece of apple root, the tree which would grow from this bud would eventually bear apples which would be exactly like those of the tree from which the bud was taken. The same situation exists with many other fruit crops and with many flowering and ornamental plants and with certain vegetable crops. Obviously then, *a primary advantage of vegetative propagation is the perpetuation of valuable varieties or individuals which in turn make for the production of a standardized product.*

Other reasons for vegetative propagation are: (1) Certain valuable plants produce little or no seed. Examples are: flowering cherry, various crab apples, Flowering Almond, flowering peach, and gardenia. (2) Other plants produce seed which germinate with difficulty. Examples are: holly, some of the viburnums, and rose. (3) Some plants are more resistant to diseases and insects when raised on roots of related plants. Examples are: European grape and peach. (4) Some plants are more hardy when grafted on the stem of other sorts. Examples are: the apple varieties—King, Baldwin, and Grimes. (5) Other plants are more vigorous. For example, grapes grafted on certain stocks produce large plants and large crops. (6) Other plants are propagated more economically by vegetative means. Examples are: strawberry, blueberry, and potato.

Methods of Vegetative Propagation

The methods of vegetative propagation are: (1) Cuttage, (2) graftage, (3) layerage, and (4) separation and division. Since these methods are distinct from each other they are discussed separately.

CUTTAGE

In cuttage, pieces of stem with or without leaves, detached whole leaves or pieces of leaves, or pieces of roots are used to produce new individuals. Detached stems with or without leaves are called stem cuttings and detached roots are called root cuttings. Of these two types, stem cuttings are used the more widely. They are classified according to the kind of plant, whether herbaceous, deciduous, or evergreen, and according to the maturity of the wood, whether softwood or hardwood, as follows: (1) The herbaceous, (2) the deciduous softwood, (3) the deciduous hardwood, and

(4) the evergreen. Since these cuttings have both similarities and differences in anatomy and maturity of the tissues, the student should have a working knowledge of these differences and similarities in order to know how to treat them for successful root production.

The Herbaceous Cutting

As the name suggests, herbaceous cuttings are taken from herbaceous plants. To produce a new individual the herbaceous stem cutting must produce a set of roots. In other words, it is a matter of producing roots from shoots. Primary considerations are: (1) The healing of the cut surface and (2) the rate of the root formation.

Healing of the Cut Surface. Rapid healing of the cut surface is indispensable to the welfare of the cutting. If the cut surface heals slowly or not at all, rot-producing organisms invade the tissues and the all-important water within the cutting escapes. Investigations, particularly at the University of Leeds, England, have shown that the herbaceous cutting heals its cut surface in the following manner: immediately after the cut is made the intercellular spaces just beneath the cut become filled with sap and the unsaturated fatty acids in the sap combine with the oxygen of the air to form a skin-like, varnish-like layer of material called suberin. Suberin possesses the remarkable property of keeping the water within the cutting and resisting the attacks of rot-producing organisms. The formation of this varnish-like layer occurs in much the same way as a layer of fresh paint changes on the surface of a building. Linseed oil, tung oil, or similar drying oils which are mixed with the pigment are unsaturated fatty acids. When the paint is spread out on the side of buildings with the pigment, the unsaturated oil readily absorbs oxygen which gives the paint a new set of properties, the most important of which is the ability to shed rain and to resist the attacks of rot-producing fungi.

The layer of *suberin* resists the attacks of organisms and retards loss of water from the cutting. However, this layer is effective for a short time only, since it is very shallow and non-elastic. If the layer of suberin is stretched it cracks easily. Hence, this layer cannot adjust itself to changes in water pressure due to the intake and outgo of water within the cutting. For these reasons a more permanent layer must be formed. This permanent layer is called the *cork layer.* How does a cutting develop this layer? Investigations have shown that the cork layer develops in the following stages: (1) Certain parenchyma cells just back of the suberized layer lose their large vacuoles and possess the function of meristematic cells. (2)

They divide and the walls of the daughter cells become impregnated with suberin, tannin, and other materials which, as previously stated, are collectively called cork. Since this layer is being renewed constantly, it is durable; since it is several cells thick, it is deep-seated; and since it is elastic, it can withstand the stress and strain due to changes in water absorption and transpiration. Thus, the cork layer possesses the ability to keep water within the cutting and to resist the attacks of invading organisms.

Rate of Root Formation. Is there anything that can be done to facilitate the development of the temporary and permanent protective layers and the production of roots with rapidity? A large number of factors are involved. These factors are placed in two groups: (1) Environmental and (2) plant.

ENVIRONMENTAL FACTORS: TEMPERATURE. Since with the herbaceous cutting the problem consists of producing roots from shoots, growth of the top is retarded and growth of the roots is facilitated. The problem, therefore, is to keep the top cool and the basal end of the cutting comparatively warm. In general, this is done by applying artificial heat to the medium in which the cuttings are placed. This application of heat to the basal portion is known as "bottom heat." "Bottom heat" is supplied in various ways—by lead covered electric resistance wire, by steam in pipes, by hot water in pipes, or by the bacterial action of manure. Many experiments have shown that high rooting media temperatures, usually within the upper half of the optimum range of any given plant, facilitate root production. For example, tests at the Ohio Experiment Station have shown that chrysanthemum cuttings kept in sand at 60° F. produced a satisfactory root system in 10 days, while a comparable lot kept in sand at 50° F. required 20 days.

RELATIVE HUMIDITY. The student will recall the importance of reducing the loss of water from the cutting. In other words, the cutting should not be allowed to dry out. How can transpiration of the cutting be retarded? What is the relation of the relative humidity to the evaporating power of the air? As stated previously, when the relative humidity is high the evaporating power of the air is low, and with other factors favorable, the rate of transpiration is low. Thus, a high relative humidity is provided. To provide a high relative humidity many kinds of practices are employed. Some cuttings are placed directly in water until they are set in the bed; others are kept in shade; and others are placed between two layers of moist cloth or paper. With some plants which callus slowly, a special propagating frame is used in which a high relative humidity is maintained.

OXYGEN SUPPLY. The formation of suberin and the rapidly dividing cambium require abundant oxygen. Hence, in the rooting of cuttings media are used which will enable the growing points to obtain abundant oxygen and, at the same time, sufficient moisture for root production. In general, fine sand, peat, mixtures of sand and peat, or vermiculite are satisfactory propagating media for herbaceous cuttings. These materials are porous, easily drained, and hold sufficient moisture for rapid root development.

Recently, scientists at the New Jersey Experiment Station have developed a method by which cuttings can be rooted without sand, peat, soil, or other solid media. The cuttings were placed in specially constructed boxes in which the stems were exposed to a very moist atmosphere. A water trough in the upper part of a box from which strips of absorbent cloth were suspended supplied the moisture necessary to maintain a high humidity. Herbaceous cuttings of begonia, chrysanthemum, coleus, geranium, perennial phlox, ivy, and philodendron produced roots in less than 3 weeks; and hardwood cuttings of hydrangea, deutzia, and philadelphus rooted satisfactorily in 6, 7, and 8 weeks.

PLANT FACTORS: THE FOOD SUPPLY. The healing of the cut surface and the production of new roots require an available carbohydrate supply. Suberin and the layer of cork and the cells of the new roots are all formed from carbohydrates. Consequently, cuttings with an abundant supply of food heal their cut surfaces more rapidly and produce roots more readily than cuttings with a scant supply. Many investigations have shown that, with other factors favorable, cuttings high in carbohydrates root more quickly than cuttings low in these compounds. Thus, cuttings from moderately vigorous plants are likely to produce roots more rapidly and satisfactorily than those from extremely vigorous or weakly vigorous plants.

THE HORMONE SUPPLY. Recent investigations have shown that substances other than foods are necessary for root production. These substances are effective in small quantities and in the extreme dilute concentration and are called hormones. The cutting may have an abundant carbohydrate supply but if the root-producing hormones are absent, the roots will develop very slowly. In the herbaceous cutting these hormones are made in the leaves.

THE LEAF AREA. The fact has been emphasized that the cutting should not be allowed to dry out. To reduce the outgo of water the leaf surface can be reduced. Is this practice generally advisable? As stated previously, carbohydrates and hormones are necessary for the development of new

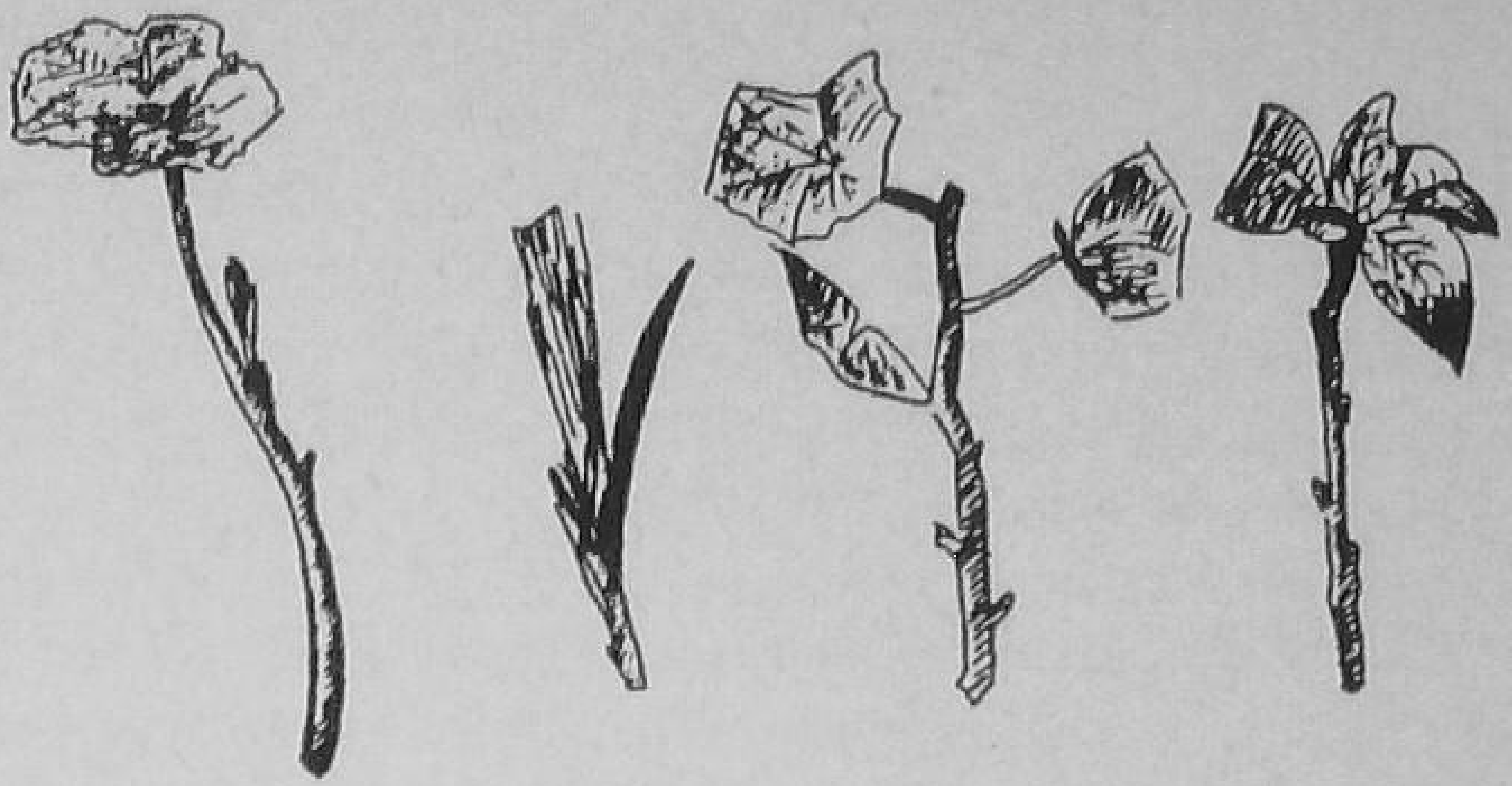


FIG. 41. Examples of herbaceous cuttings. (*Left to right*) Geranium, carnation, coleus, and impatiens. (Redrawn from *Md. Agr. Exp. Sta. Bul. 335*, 1932.)

roots. These carbohydrates and hormones are made in the leaves. Consequently, if reduction of the leaf area is necessary, it should be reduced only enough to prevent wilting, and a high relative humidity should be maintained to keep the leaves turgid.

ACTIVITY OF THE ROOT-PRODUCING TISSUE. The tissues of the herbaceous stem are: epidermis, cortex, endodermis, pericycle, primary phloem, primary xylem, and pith. Which of these tissues possesses the ability to form roots? As stated previously, the pericycle possesses the ability to revert to the meristematic condition and thus form new growing points. These new growing points develop into roots. Therefore, in the production of new roots from shoots success depends in part on the activity of the pericycle.* Certain plants have a fairly well-developed pericycle, and others have not. This may explain, in part at least, why some cuttings root relatively easy and why others root with difficulty. Figure 41 shows herbaceous cuttings of four kinds of plants. Left to right: geranium, carnation, coleus, and impatiens.

Leaf Cuttings. Leaf cuttings consist of whole leaves or pieces of leaves. They usually are taken from plants which develop thick, fleshy leaves and are prepared in much the same way as the herbaceous cutting. As in the case of stem cuttings, wilting of leaf cuttings should be avoided.

The Deciduous Softwood Cutting

Deciduous softwood cuttings are taken from deciduous woody plants, usually when the twigs cease to elongate. At this time the tissue is said to be in the half-ripe or half-mature condition. Since elongation of the

*With some kinds, other tissues, cortex, and pith, may form new growing points.

twigs has just ended, *they have had little opportunity to store carbohydrates.* Principal factors concerned are: (1) The necessity for leaves and (2) the activity of the wound and vascular cambiums. Since the softwood cutting has had little opportunity to store carbohydrates, the supply of food and hormones must be obtained through the action of the leaves. For this reason leaves are necessary in rooting deciduous softwood cuttings and, as with the herbaceous cutting, the leaves should be maintained in the turgid condition. In general, the greater the leaf area, within limits, the greater is the rate of root formation. The wound and vascular cambium possess the ability to form new growing points which develop into roots. Investigations have shown that with crops propagated by softwood cuttings some root best when the cut is made at the node; others root best when the cut is made just below the node; others root best when the cut is made just above the node; while others are indifferent to the position of the basal cut. Can you think of any reason for this? Examples are shown in Table 17.

Table 17

VARIATION IN POSITION OF BASAL CUT IN ROOTING OF CUTTINGS*

Position of Cut for Best Rooting	*Kind of Plant*
At the node	cotoneaster, ginkgo, scarlet firethorn, Siebold viburnum
Just (½ in.) below the node	Japanese barberry, flowering dogwood, Amur privet, honeysuckle, spirea
Just (½ in.) above the node	California privet, European privet, pink weigela
No preference	deutzia, cherry elaeagnus, border forsythia, common winterberry

*From: The vegetative propagation of plants, *Md. Agr. Exp. Sta. Bul. 335*, 1932.

The Deciduous Hardwood Cutting

Deciduous hardwood cuttings are taken from woody plants during the non-growing season. *At this time the wood is mature and well supplied with carbohydrates.* Principal factors concerned are: (1) The activity of the buds and (2) the ability of the vascular and wound cambiums to heal the cut surface and to form new roots. Buds produce root-forming hormones. These hormones are translocated from the bud to the base of the cutting. Investigations have shown that with some plants the terminal bud

produces more root-forming hormones than lateral buds. As with the softwood cutting, the vascular cambium and the wound cambium possess the ability to form new roots. In general, roots which develop at the base of the cut arise from the wound cambium, and those which develop from the nodes arise from the vascular cambium. Since both types of meristematic tissue are more active at the nodes than at the internodes, the basal cut is made just below the bud. Operations in the handling of this type of cutting are: (1) Securing the cutting during the non-growing season (usually, medium-sized wood from 6 to 10 inches long), (2) healing over the cut surface during the winter, (3) planting in the field in the spring, and (4) allowing the cuttings to grow for a season or two before they are transplanted. Figure 42 shows hardwood cuttings of four kinds: grape, mock orange, forsythia, and currant.

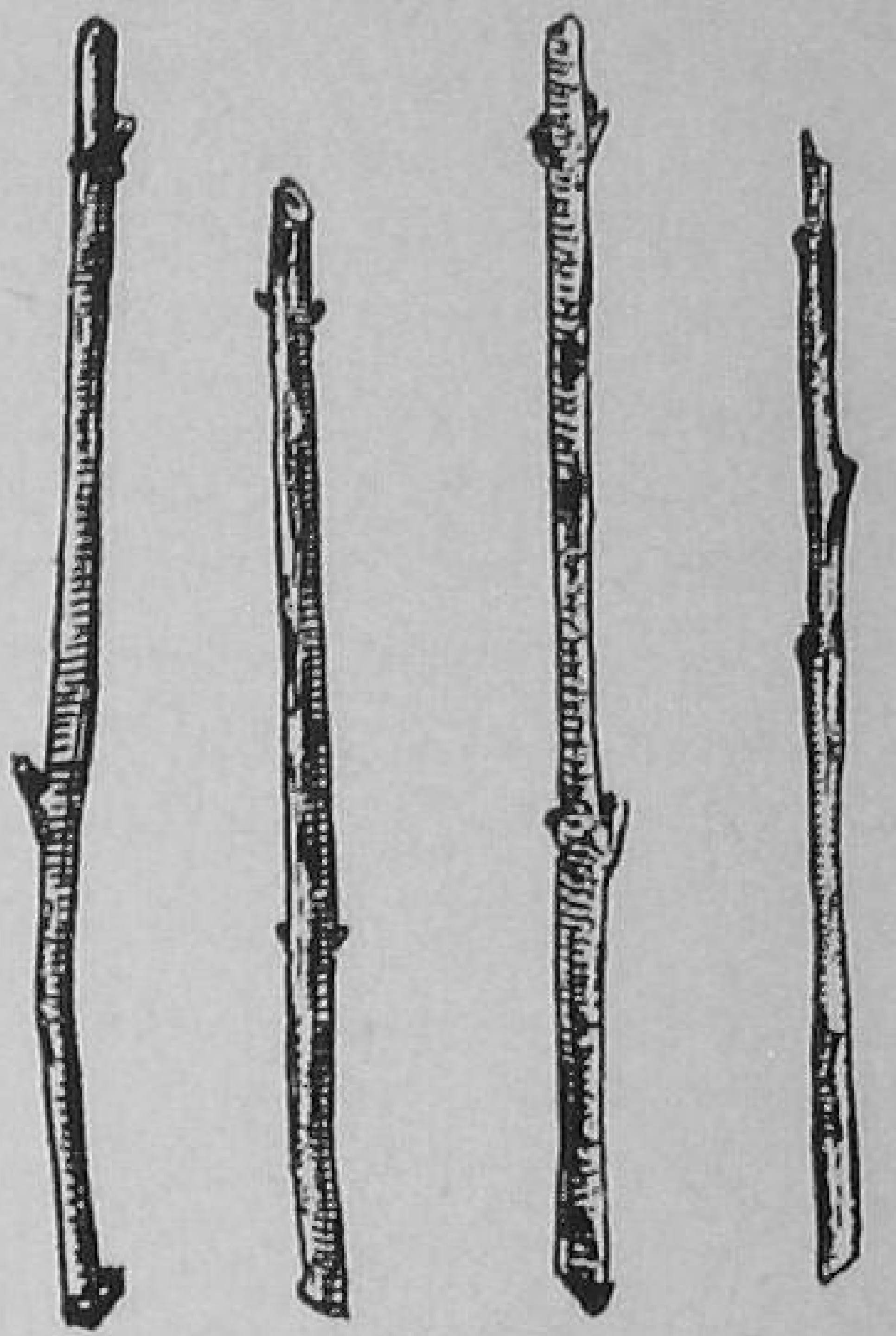


FIG. 42. Examples of hardwood cuttings. (*Left to right*) Grape, mock orange, forsythia, and currant. (Redrawn from *Md. Agr. Exp. Sta. Bul.* 335, 1932.)

The Evergreen Cutting

Evergreen cuttings are taken from coniferous and broad-leaved evergreens. The principal factors concerned are: (1) The maturity of the wood and (2) the supply of carbohydrates and root-forming hormones. Many experiments have shown that the wood of evergreen cuttings roots best when it is partially mature. Apparently, the wound and vascular cambiums are most active in immature wood. *Since the wood is immature, little if any carbohydrates are stored in the tissue, and as a result leaves are necessary.*

The time of year evergreen cuttings are taken varies with the type of plant. In general, coniferous cuttings are taken in the fall or early winter and are rooted in forcing structures where bottom heat is available. Broad-leaved cuttings are usually taken in the late summer and rooted in outdoor frames. Figure 43 shows broad-leaved evergreen cuttings. Left to right: Glossy privet, boxwood, euonymus, and holly.

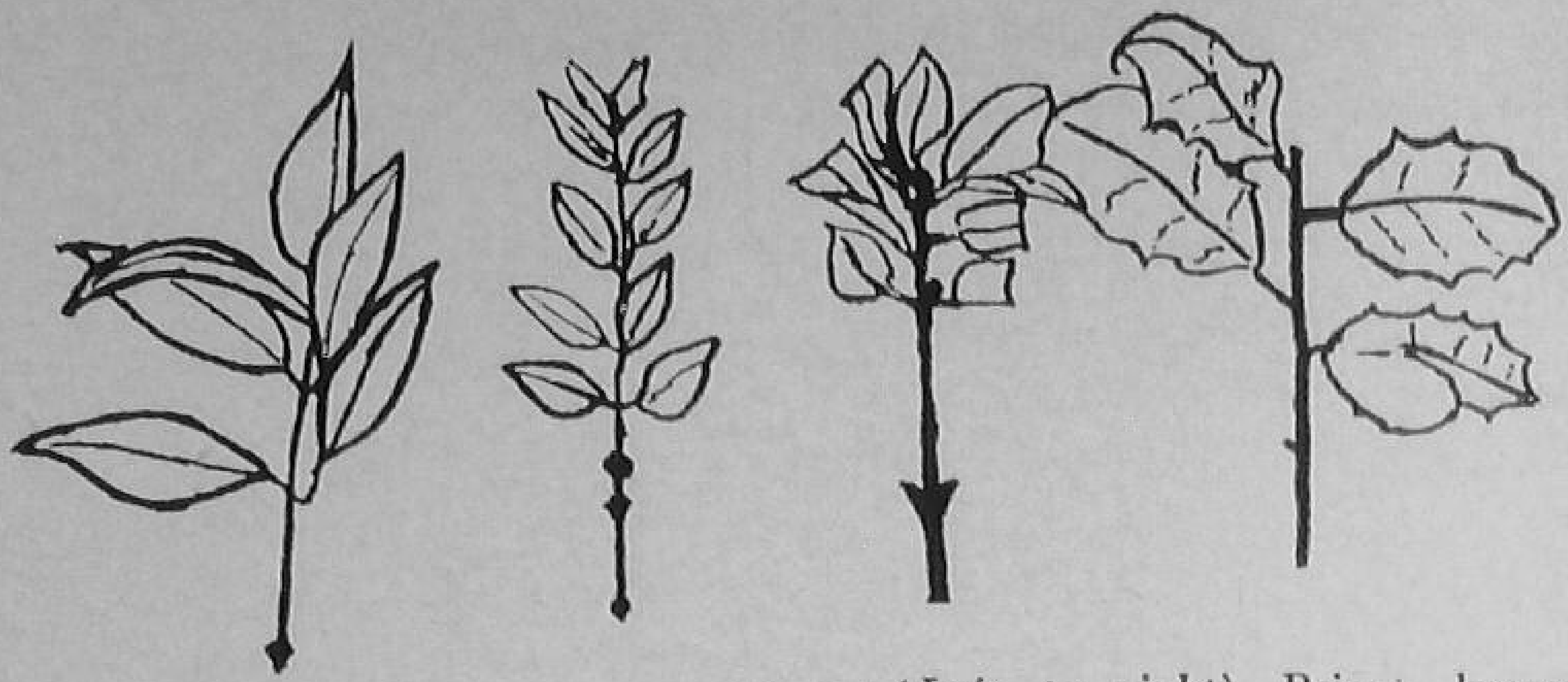


FIG. 43. Examples of evergreen cuttings. (*Left to right*) Privet, boxwood, euonymus, and holly. (Redrawn from *Md. Agr. Exp. Sta. Bul. 335*, 1932.)

Chemical Treatments and Rooting of Stem Cuttings

Many investigations have shown that the application of certain chemicals promotes the development of roots in the four types of stem cuttings. Of the numerous chemicals which have been tried indoleacetic acid, indolebutyric acid, and naphthaleneacetic acid have produced the most striking results. These chemicals not only speed up root production but they also induce the development of a large number of roots and are now used widely in the propagation of many plants. They may be applied in the form of a paste, liquid, or dust. When solutions are used the type of cutting, concentration of the chemical, and period of soaking must be considered. In general, using a concentration of 5 milligrams of indolebutyric acid in 100 cc. of water, cuttings which root easily are treated for a period of about 6 hours; those which root moderately well are treated for a period of about 12 hours; and those which root with difficulty are treated for a period of 24 to 48 hours.

Root Cuttings

Root cuttings are pieces of roots and are used to propagate certain woody plants. The cuttings are made when the wood is mature and are handled in much the same way as hardwood cuttings. New shoots develop from adventitious buds, and new roots develop from the old root or from the base of the new individual.

In general, root cuttings are made 2 to 6 inches long from roots about the size of an ordinary lead pencil. There are two methods by which the cuttings are handled. The first consists of taking the cuttings in early winter, storing them in sand, and planting them the following spring. The second consists of starting the cuttings in hotbeds or greenhouses in winter,

and transplanting the young plants to the field the following spring. The cuttings may be planted either horizontally or vertically. If they are planted vertically, the end next to the crown of the plant is placed uppermost. Plants which develop "suckers" readily are propagated easily by root cuttings. Table 18 lists examples of plants propagated by the various types of cuttings.

Table 18

KINDS OF CUTTING USED IN PROPAGATING CROPS

Kind of Cutting	*Horticulture Plants*
Herbaceous stem ...	chrysanthemum, carnation, begonia, geranium
Leaf	begonia, bryophyllum, gloxinia, *Saintpaulia*
Deciduous softwood .	spirea, lilac, viburnum, weigela, Japanese barberry, dogwood
Deciduous hardwood.	gooseberry, currant, mulberry, grape, fig
Evergreen	Japanese yew, juniper, arbor vitae, privet, boxwood, azalea, holly
Root	blackberry, bouvardia, wisteria

Questions

1. State the prime reason for vegetative propagation. State four other reasons for vegetative propagation.
2. State the four general methods of vegetative propagation.
3. Name the four different kinds of stem cuttings.
4. Show how a relatively high temperature and high humidity facilitate rapid healing of the cut surface of herbaceous cuttings.
5. In general, immediately after herbaceous cuttings are made they should be placed in a humid atmosphere. Explain.
6. Herbaceous cuttings while being prepared should not be placed in the hot sun or in wind. Explain.
7. Investigations have shown that herbaceous cuttings of many flower crops root better at 70° F. than at 60° F. Explain.
8. Given two lots of cuttings. Lot A is placed in dry air, a humidity of 40 per cent. Lot B is placed in moist air, a humidity of 90 per cent. Other factors being equal, which lot has the greater percentage of survival? Give your reasons.
9. Florists use sand, peat, and mixtures of sand and peat instead of loam for propagating cuttings. Explain.
10. Coarse sand is less satisfactory than fine sand as propagating material. Explain.

11. Herbaceous cuttings taken from moderately vigorous plants produce more roots in a given time than those taken from extremely vigorous plants. Explain.
12. In general, the tips of shoots produce less roots in a given time than portions just back of the tips. Explain.
13. The leaf area of herbaceous cuttings should not be reduced if wilting can otherwise be avoided. Explain.
14. Sweetpotato vine cuttings have a very active pericycle. Under favorable conditions they root easily. Explain.
15. Given two lots of softwood cuttings. Lot A has two leaves, lot B has one leaf. With environmental factors favorable, which lot is likely to produce more roots in a given time? Give your reasons.
16. Many species of woody plants root better at the nodes than at the internodes. Explain.
17. In the hardwood cutting, why is the cut made just below a bud? Explain.
18. Propagators make an inclined cut rather than a horizontal cut in hardwood cuttings. Explain.
19. Hardwood cuttings are stored in cool moist situations. Explain.
20. Burying hardwood cuttings with the butt end up stimulates root production and keeps buds dormant. Explain.
21. Leaves are necessary for the production of roots in the softwood and evergreen cutting. They are unnecessary for the production of roots in the hardwood cutting. Explain.
22. What is a "sucker"?
23. Crops which produce suckers readily can be satisfactorily propagated by root cuttings. Explain.

GRAFTAGE

What is Graftage? Graftage involves the union of two separate structures—the union of a root and a stem, or more frequently, the union of two separate stems. For successful union of the two structures, contact of the cambiums of each structure is necessary. In other words, the cambiums of one structure must be placed in contact with the cambiums of the other structure in order that the two may grow together.

Reasons for Graftage. Graftage makes possible: (1) The propagation of plants which are less effectively propagated by other methods; (2) the changing of undesirable varieties to desirable varieties or the growing of several kinds of flowers or fruit on one tree or plant; and (3) the utilization of the root system of plants which are resistant to unfavorable soil conditions, low temperature, or to certain soil pests. Examples are: the failure of many varieties of apple, pear, peach, plum, cherry, pecan, citrus, and ornamentals to form roots readily and the susceptibility of the roots

of European grape varieties to the root louse—Phylloxera, and the susceptibility of certain peach varieties to nematodes.

Types of Graftage. Two types are recognized: (1) Budding and (2) grafting. Budding consists of uniting a vegetative bud to a seedling tree or to a mature tree. Grafting consists of uniting a group of vegetative buds to a seedling tree or to a mature tree. This group of vegetative buds is called a cion. Thus, the chief difference between budding and grafting is that a single bud is used in budding, and a piece of stem or a group of buds is used in grafting. In general, buds located in the mid-portion of the one-year-old wood make the best unions. The structure which is united to the bud or cion is called the stock. For most crops propagated by graftage, the stocks consist of seedling trees which are usually, but not always, raised from seed. Thus, both sexual and asexual propagation supplement each other in graftage operations.

Budding

Kinds of Budding. The different kinds of budding are classified according to the manner in which the bark of the stock is prepared to receive the bud. The most important kinds are T-budding and patch-budding.

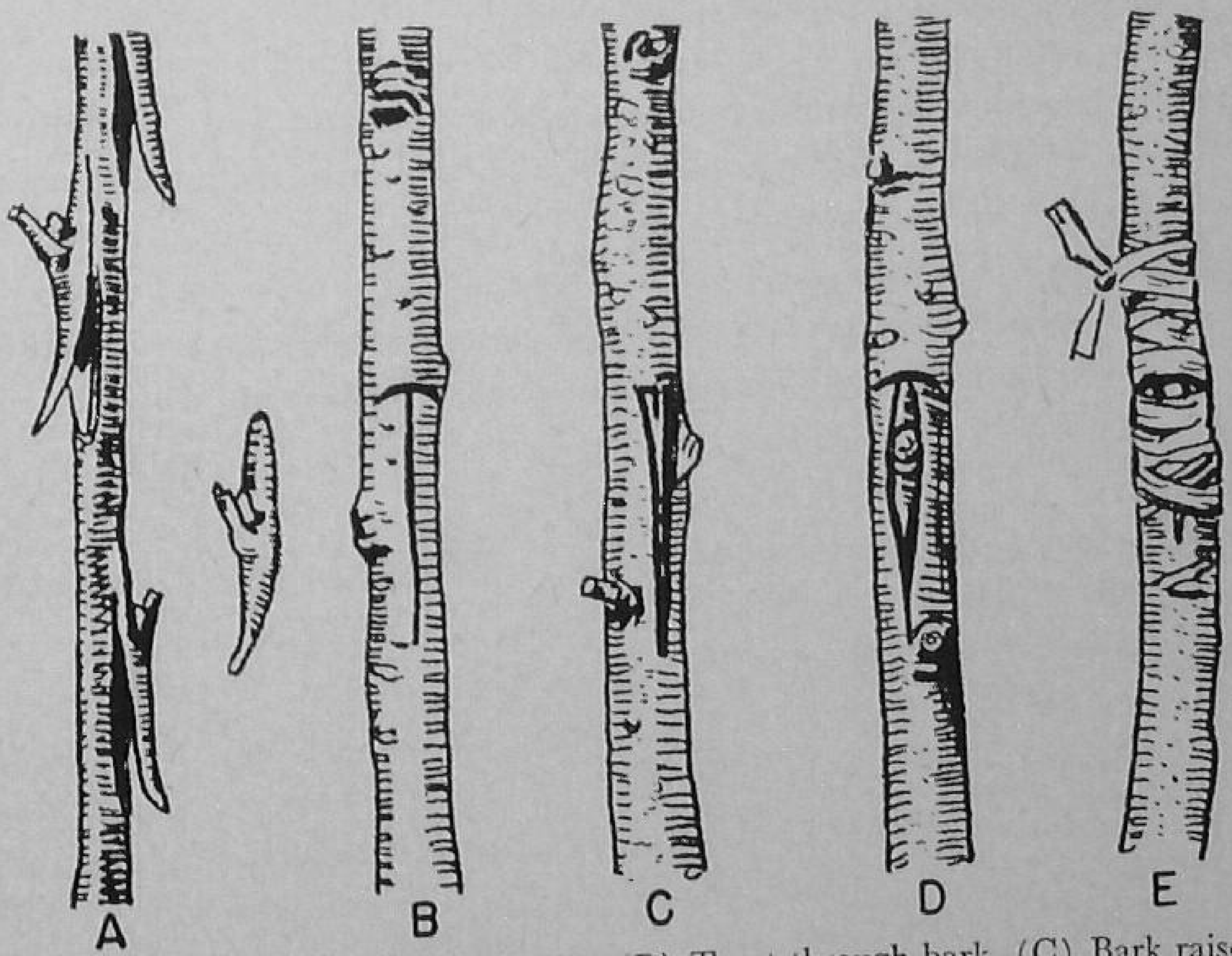


FIG. 44. T-budding. (A) Bud stick. (B) T cut through bark. (C) Bark raised to admit bud. (D) Bud in place. (E) Bud wrapped in raffia. (Redrawn from *U.S. Dept. of Agr. Farmers' Bul. 1567*, 1932.)

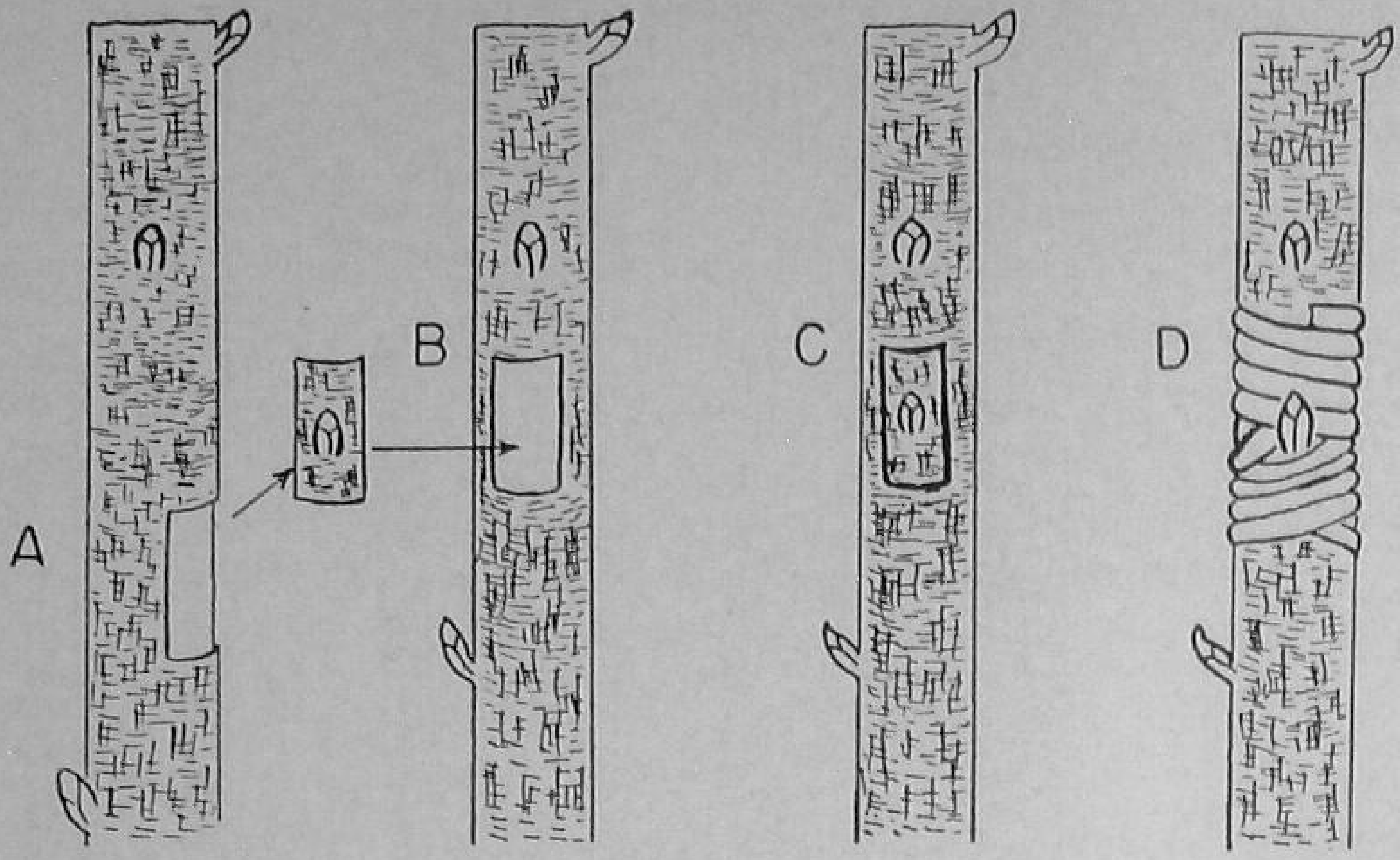


FIG. 45. Patch-budding. (A) Cion removed from bud stick. (B) Patch of bark removed from stock. (C) Cion from (A) inserted in (B). (D) Cion wrapped with waxed cloth. (Redrawn from *Miss. Agr. Exp. Sta. Bul. 375*, 1943.)

T-BUDDING. T-budding consists of making a cut in the bark of the stock in the form of a T and inserting the bud under the bark. Raffia, rubber bands, or adhesive tape are used to hold the bud tightly to the stock. T-budding is commonly used in the propagation of peaches (see Figure 44).

PATCH-BUDDING. This consists of removing a square or rectangular piece of bark from the stock and replacing it by a similar patch of bark which includes the desirable bud. The wrapping material usually used is waxed cloth or budding tape. Patch-budding is commonly used in the propagation of thick-barked trees such as pecan and walnut (see Figure 45).

Grafting

Kinds of Grafting. The different kinds of grafting are classified according to the method of placing the cion on the stock. These kinds are: (1) Root grafting, (2) top grafting, (3) bridge grafting, and (4) inarching.

ROOT GRAFTING. Root grafting consists of placing a cion, 4 to 6 inches long, on the root or piece of a root of seedling trees. This type of grafting is used extensively in the propagation of apples and pears. One-year-old seedlings are dug in the fall and the grafting is done in the winter. The whip or tongue graft is commonly used to join the one-year-old seedling and the cion. Sloping cuts about 1½ inches long are made at the base of the cion and at the top of the stock, and a reverse cut is made on each

piece about ⅓ inch from the tip and ½ inch in depth. The two pieces are then fitted together and wrapped (see Figure 46).

Top Grafting. Top grafting consists of placing one, two, or four cions, each 4 to 6 inches long, on branches not thicker than 2 to 4 inches in diameter. It is used to change from one variety of fruit to another variety. The cleft graft, bark graft, and notch graft are used in top grafting.

cleft grafting. Cleft grafting consists of: (1) Splitting the stock branch down the center, (2) holding the wedge open while the cion is inserted, (3) placing the cion in the cleft in such a way as to insure contact of the two cambiums, and (4) waxing over the cut surface. The main advantage of cleft grafting is that it can be done during the dormant season. Its main disadvantage is that wood-decaying organisms may get into the graft (see Figure 47).

bark grafting. Bark grafting consists of: (1) Slitting the bark of the stock, (2) nailing the cion in place, and (3) waxing over the cut surface. Bark grafting can be done only in the spring when the bark begins to slip. The cion wood must be gathered when dormant and stored until needed.

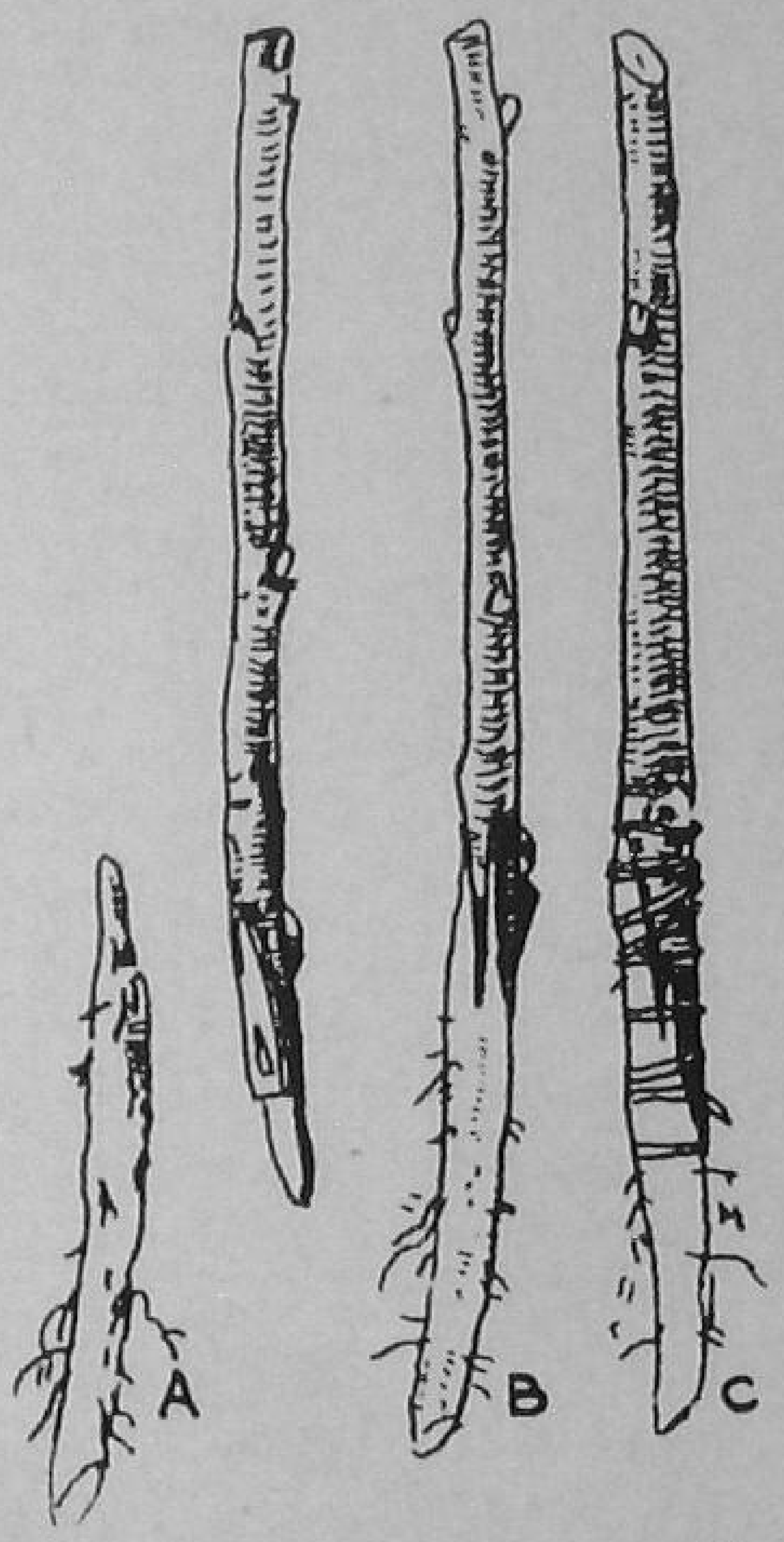


Fig. 46. Root, tongue, or whip grafting. (A) Cion and stock prepared. (B) Cion and stock fitted together. (C) Cion and stock wrapped with raffia. (Redrawn from *U.S. Dept. of Agr. Farmers' Bul. 1567*, 1932.)

notch grafting. Notch grafting consists of: (1) Notching the bark of the stock, (2) cutting the piece of the cion to fit the notch, (3) nailing the cion in place, and (4) waxing over the cut surface. Notch grafting combines the advantages of cleft and bark grafting, since it can be done over a considerable period of time and the stock is not split. However, notch grafting, when properly done, requires considerable time.

The care of top worked trees is just as important as the grafting opera-

tion. Treatment consists of: (1) Whitewashing the tree to reduce sunscald to a minimum, (2) rewaxing all cracks on the original waxed surface, (3) removing water sprouts below unions which may hinder the growth of the cions, and (4) protecting young shoots from strong winds.

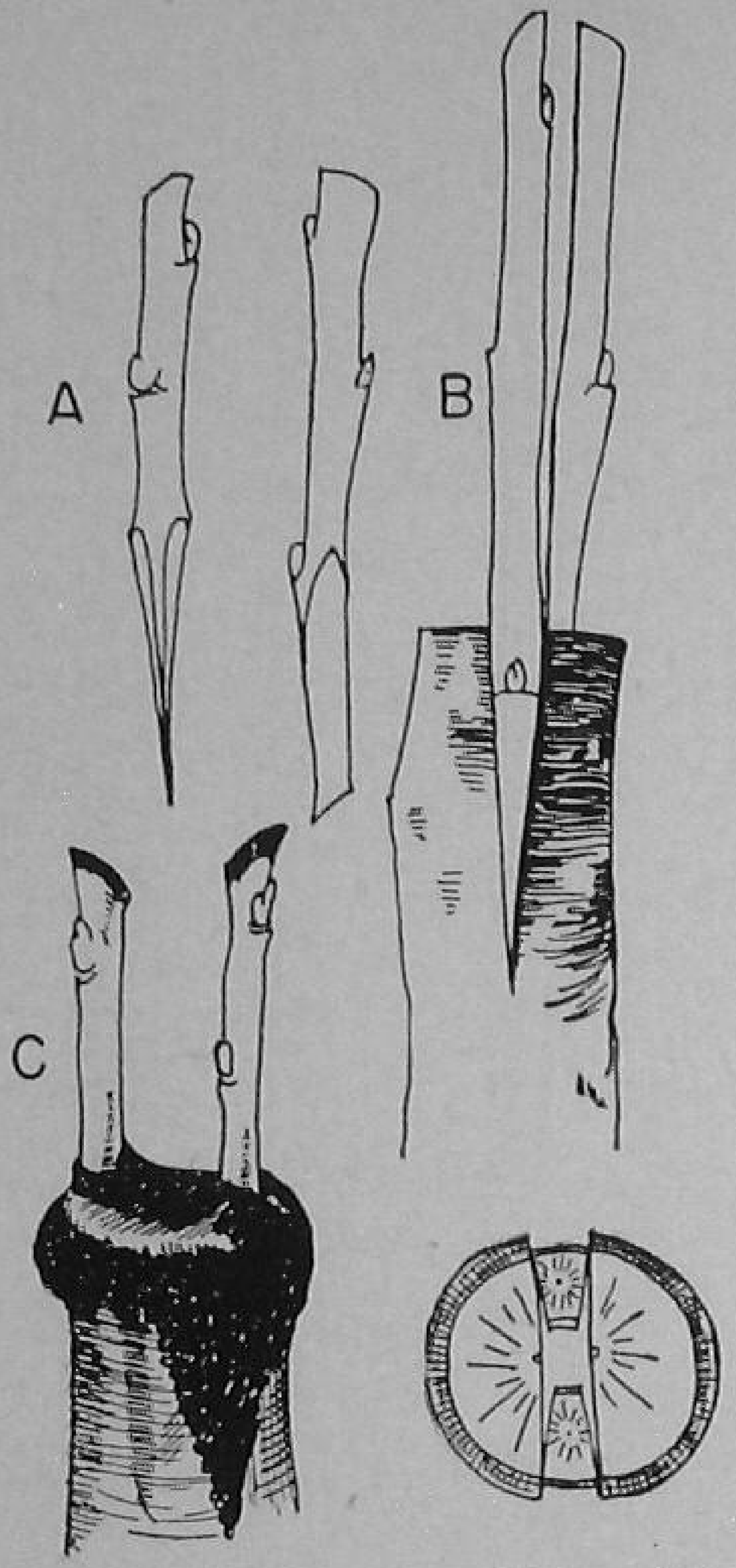


FIG. 47. Cleft grafting. (A) Cions prepared. (B) Cions inserted in stock. (C) Cut surface waxed. (Redrawn from *U.S. Dept. of Agr. Farmers' Bul. 1567*, 1932.)

BRIDGE GRAFTING. Bridge grafting consists of inserting one-year-old cions above and below injured areas of trunks or limbs. Each year many trees are girdled partially or completely by rodents or by mechanical means. The bridging of the injured area saves the tree. The cions usually are collected during the dormant season and are inserted in the tree when the bark begins to slip (see Figure 48).

INARCHING. Inarching consists of uniting the stems of two separate plants while they are growing on their own roots. In the inarching of fruit trees a seedling tree is planted beside an old tree. When the seedling tree has become established, the stem is inserted in the trunk of the old tree. In the inarching of certain evergreens, the plants used as stocks are potted and placed close to the plants which are to be used as cions. The bark on one side of the stem of the stock is sliced away for a distance of 1 or 2 inches. A similar cut is made on the side of the cion. The two wounded surfaces are then pressed together and bound with waxed cloth, waxed strips, or tape to prevent drying out of the cut surface. The stock and cion are allowed to remain undisturbed throughout the growing season during which time the tissues will have united. Inarching, while not extensively used in the propagation of plants, is a more certain method of grafting ornamentals which are propagated with difficulty by other methods. Its chief advantage is that the cion is supported by the parent plant while the tissues of the two structures are uniting.

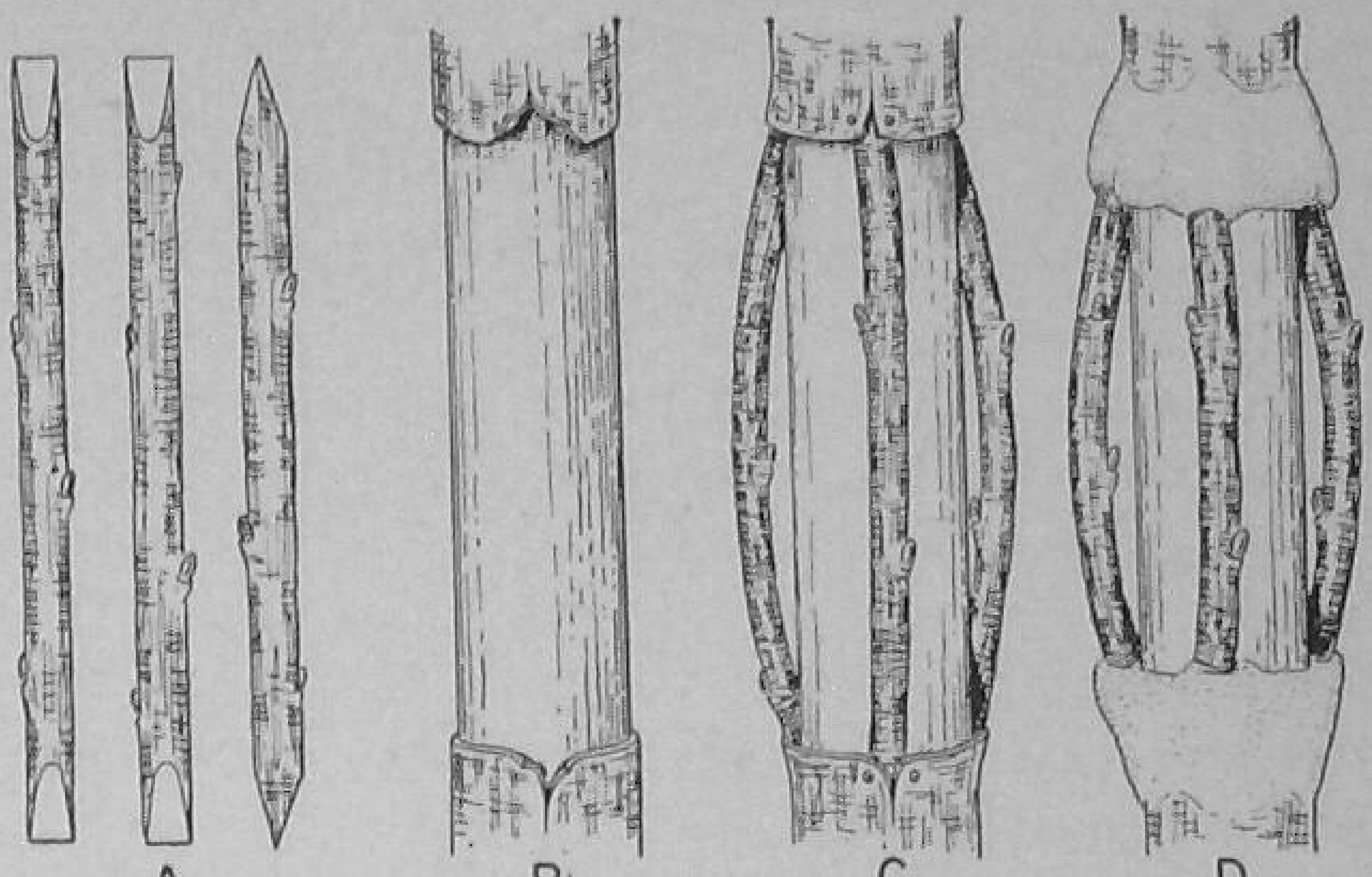


FIG. 48. Bridge grafting. (A) Three views of prepared cion. (B) Injured area prepared to receive cions. (C) Cions inserted. (D) Cions and bark waxed. (Adapted from *Calif. Agr. Ext. Cir. 96*, 1936; and *Miss. Agr. Exp. Sta. Bul. 375*, 1943.)

Grafting Waxes and Tools. Many types of waxes and tools are used in budding and grafting. The primary function of waxes is to protect the wounded surfaces from wood-decaying fungi, to retard transpiration from the tissues, and to permit the normal exchange of oxygen and carbon dioxide in respiration. For these reasons, suitable waxes must not crack or melt at ordinary temperatures and must be free from substances toxic to the tissues. Various kinds of waxes are: (1) *Hand wax,* consisting of rosin 4 pounds, beeswax 2 pounds, and tallow or lanolin 1 pound; (2) *alcohol wax,* consisting of pure rosin 2 pounds, beeswax 1 pound, and ethyl alcohol about 180 cc.; (3) *hard wax,* consisting of rosin 4 pounds, beeswax 1 pound, linseed oil 1 pint or tallow 1 pound, and lamp black 1 ounce; and (4) *paraffin wax.* Emulsified asphalt is satisfactory for covering wounds in the spring and late fall, but it injures fresh tissue in hot weather. Tying materials are cotton twine, raffia—the epidermis of the Madagascar palm —corn shucks, nursery tape, waxed string, and waxed muslin. Tools used in plant propagation are various types of knives; budding, grafting, and patch budders; clipped irons; chisels; pruning saws, and shears.

LAYERAGE

Layerage consists of supplying favorable conditions for the rooting of stems while they are attached to the plant. The part of the stem which is

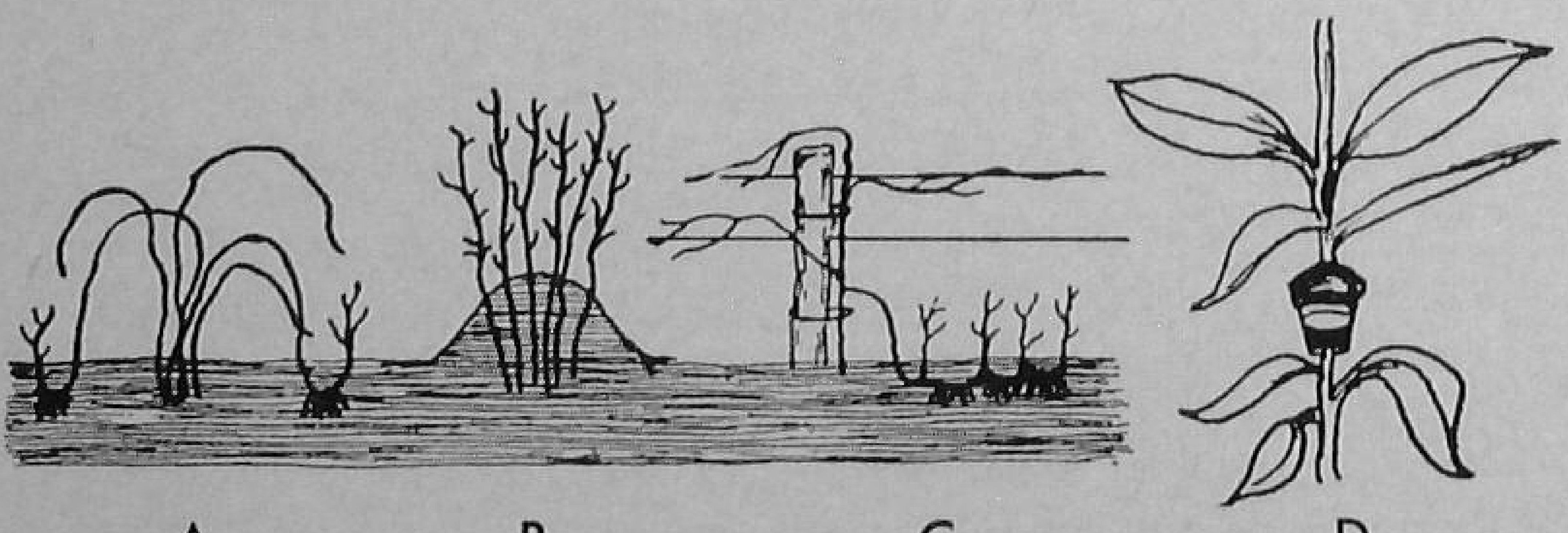
to produce roots should be kept warm and moist. What is the relation of temperature and the moisture supply to the development of roots?

Layerage is usually accomplished by covering the stem with moist soil or peat. A particular advantage of this type of propagation is that the parent plant supplies the layered shoots with carbohydrates, hormones, water, and nutrients until the buds develop sufficient roots and leaves to take care of themselves. When the young shoot has developed sufficient roots it is severed from the parent plant. The principal types of layerage are: (1) Tip, (2) mound, (3) trench, and (4) pot or air. These are illustrated in Figure 49.

Tip Layering. Tip layering consists of drawing a shoot to the earth and covering it a short distance behind the tip with soil. In some cases the entire tip is covered with soil through which the new shoot grows. Black raspberries, trailing blackberries, loganberries, and dewberries can be propagated in this way.

Mound Layering. Mound layering consists of cutting back the stems of the plant in the spring and covering the stubs with a mound of soil. In this way the new shoots which develop from the stems produce roots in the soil. These new shoots usually are removed the following fall or spring and are set out as separate plants. Currants, gooseberries, and quinces are propagated by this method.

Trench Layering. Trench layering consists of placing a stem in a shallow trench. When the new shoots are a few inches long, soil is pulled around them and again at frequent intervals until the trench is filled. Muscadine grapes are propagated by this method. The canes are placed in trenches during the late fall or winter, and shoots develop from the nodes during the following spring or summer. In late fall or early spring the new plants



A B C D

FIG. 49. Types of layerage. (A) Tip layering. (B) Mound layering. (C) Trench layering. (D) Pot layering. (Adapted from *Mo. Agr. Exp. Cir. 191*, 1936.)

may be removed from the parent stem. With some plants wounding is necessary to induce root formation. For example, rhododendron stems are notched, ringed, or slit.

Pot or Air Layering. Pot layering consists of surrounding the stem of the plant with soil or moss held in place by a split-pot or box. In general, the stem is girdled to facilitate the production of roots just above the girdle. When the roots are well developed the stem can be severed from the parent plant. In general, pot layering is very troublesome and is used only on choice and indoor plants. It is practiced usually with such plants as *Codiaeum* and *Ficus*.

SEPARATION AND DIVISION

The formation of new individuals by separation and division consists essentially of separating or dividing parent plant parts which in turn produce new individuals. Separation consists of removing natural vegetative entities such as bulbs or corms. Division consists of cutting or dividing fleshy storage organs, chiefly rhizomes and tubers.

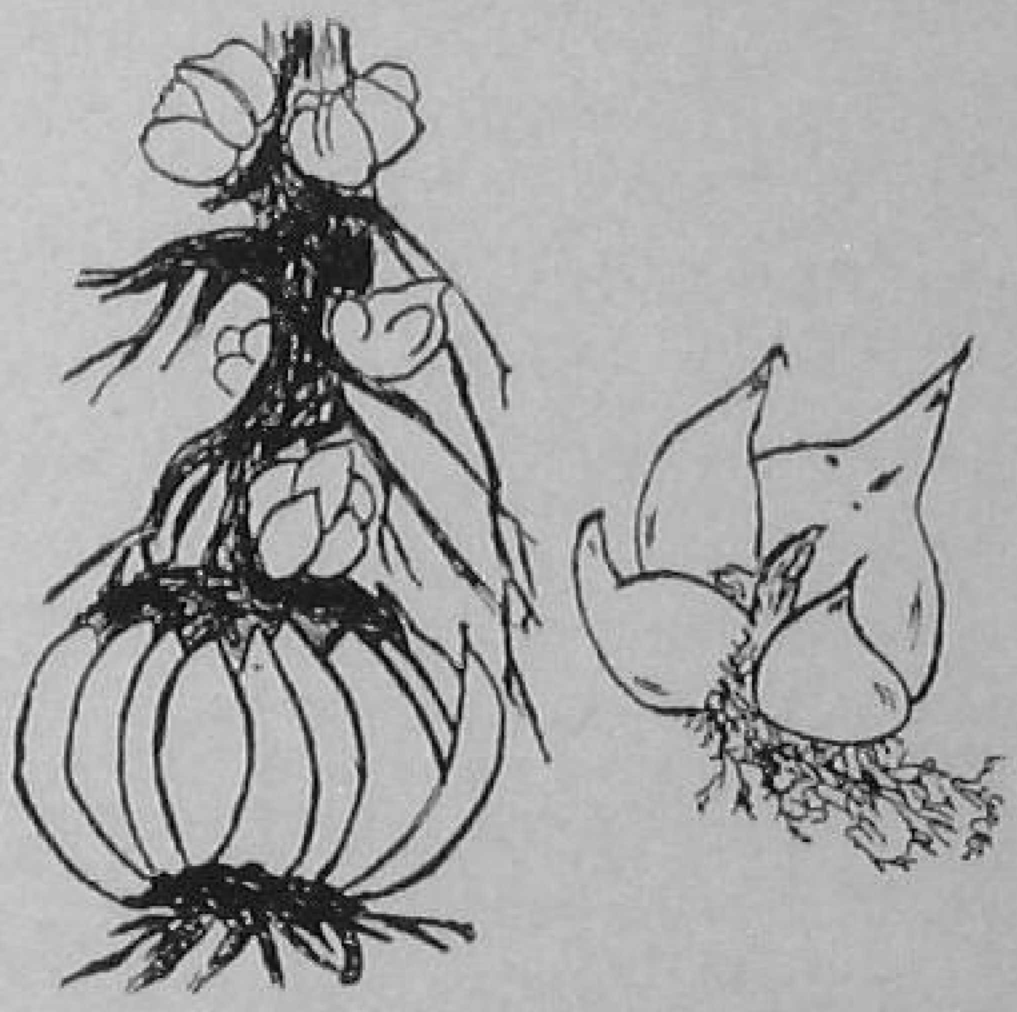


Fig. 50. Young and old bulbs of lily and tulip. (Redrawn from *Calif. Agr. Ext. Cir. 132,* 1947; and *U.S. Dept. of Agr. Cir. 372,* 1936.)

Bulbs. A bulb is a short thickened stem surrounded by a group of fleshy basal leaves. The scales of the bulbs are the fleshy leaves. Roots arise from the basal portion of the bulb known as the stem plate and shoots arise from the nodes of the stem. In many cases small bulbs form around, on top, or at the base of the mother bulb. When the bulbs are removed from the soil, the young bulbs are separated from the old bulbs and are planted separately the following season. Easter lilies and certain onions are propagated in this way. Note the young bulbs of lily and tulip in Figure 50.

Corms. A corm is a solid structure. They produce small corms in the soil in much the same way as bulbs produce small bulbs. These corms, sometimes called cormels, are handled in the same manner as small bulbs. Gladiolus and crocus produce corms and are, of course, propagated by the planting of small cormels.

Tubers. A tuber is a short, thick, fleshy underground stem with scale-like leaves subtending eyes or nodes. Examples are the tubers of the potato and Jerusalem artichoke. Shoots arise from the eyes and develop into independent plants. In the propagation of the potato large tubers are cut into several pieces. Each piece has one or more eyes and stored food, chiefly starch, for the nourishment of the seedling plant.

Fleshy Roots. Some horticultural crops develop thick, fleshy roots. These roots are used to propagate the plants asexually. An example is the fleshy roots of sweetpotato. Shoots arise from adventitious buds which develop into young plants. The root system of the plants arises from the nodes of that portion of the stem underneath the surface of the soil. For the rapid development of the young plants the fleshy roots are bedded in various types of hotbeds. Relatively high temperatures and moist bedding media are maintained.

As stated before, division consists of dividing fleshy underground stems—usually rhizomes. In general, rhizomes which are well developed and contain a large number of buds are used. Division is done usually in the spring or late fall and seldom in the summer. Many herbaceous perennials are propagated by division—lily of the valley, aster, hollyhock, violet, rudbeckia, gaillardia, coreopsis, chrysanthemum, shasta daisy, campanula, phlox, delphinium, and rhubarb.

Questions

1. Differentiate between grafting and budding.
2. What is meant by: the term stock? the term cion?
3. Practically all deciduous and evergreen fruit crops are propagated by budding or grafting. Explain.
4. The cambium is the chief tissue concerned in the union of woody stems. Explain.
5. Budding and grafting are limited to deciduous and coniferous plants. Explain.
6. In the budding of fruit crops the buds are wrapped tightly until they form a union with the stock. Explain.
7. In the South, peach budding usually is done in June; in the North, in August. Explain.
8. Why are grafts usually not planted immediately after the graft is made?
9. Burying hardwood cuttings with the butt end up stimulates root production and keeps buds dormant. Explain.
10. When making a cleft graft, the end of the stub is covered with soft grafting wax while other grafts are usually wrapped with waxed string. Explain.

11. In general, Mahaleb cherry stocks are better than Mazzard cherry stocks. Explain.
12. How does inarching differ from ordinary grafting?
13. Name the four types of layering.
14. How does layering differ from grafting?
15. The stems of plants propagated by pot layering are girdled at the place where roots are to be produced. Explain.
16. Differentiate between separation and division.
17. Separation and division usually are made when the storage organs are full of carbohydrates. Explain.

8

Climates, Sites, and Soils

Assignment 13

CLIMATES

The United States is a big country. It is about 3000 miles wide, from 1500 to 2000 miles long, and comprises an area of 3,026,789 square miles. Within this large area there is a wide variation in the environmental factors which influence plant growth and development. In particular, there are marked variations in temperature, intensity and duration of sunshine, direction and intensity of the wind, relative humidity of the atmosphere, and kind, amount, and distribution of rainfall. In fact, the variation in these climatic factors is so wide that different climates exist in the United States. These climates are classified as follows: (1) The cool-humid climate of the Northeast and Great Lakes, (2) the warm-humid climate of the Southeast and Gulf Coast, (3) the sub-humid climate of the Great Plains, (4) the arid climate of the Intermountain region of Idaho, Utah, Colorado, New Mexico, Arizona, and California, and (5) the summer-dry climate of the Pacific Coast. The student should keep in mind that the climates of adjacent regions gradually merge into each other. Note the boundary of each region in Figure 51.

Climate of the Northeast and Great Lakes Region. This climate is characterized by comparatively cool summers, long cold winters, moderate rainfall, and moderate light intensity. The frost-free growing season varies from 80 days in the central part of the Upper Peninsula of Michigan to

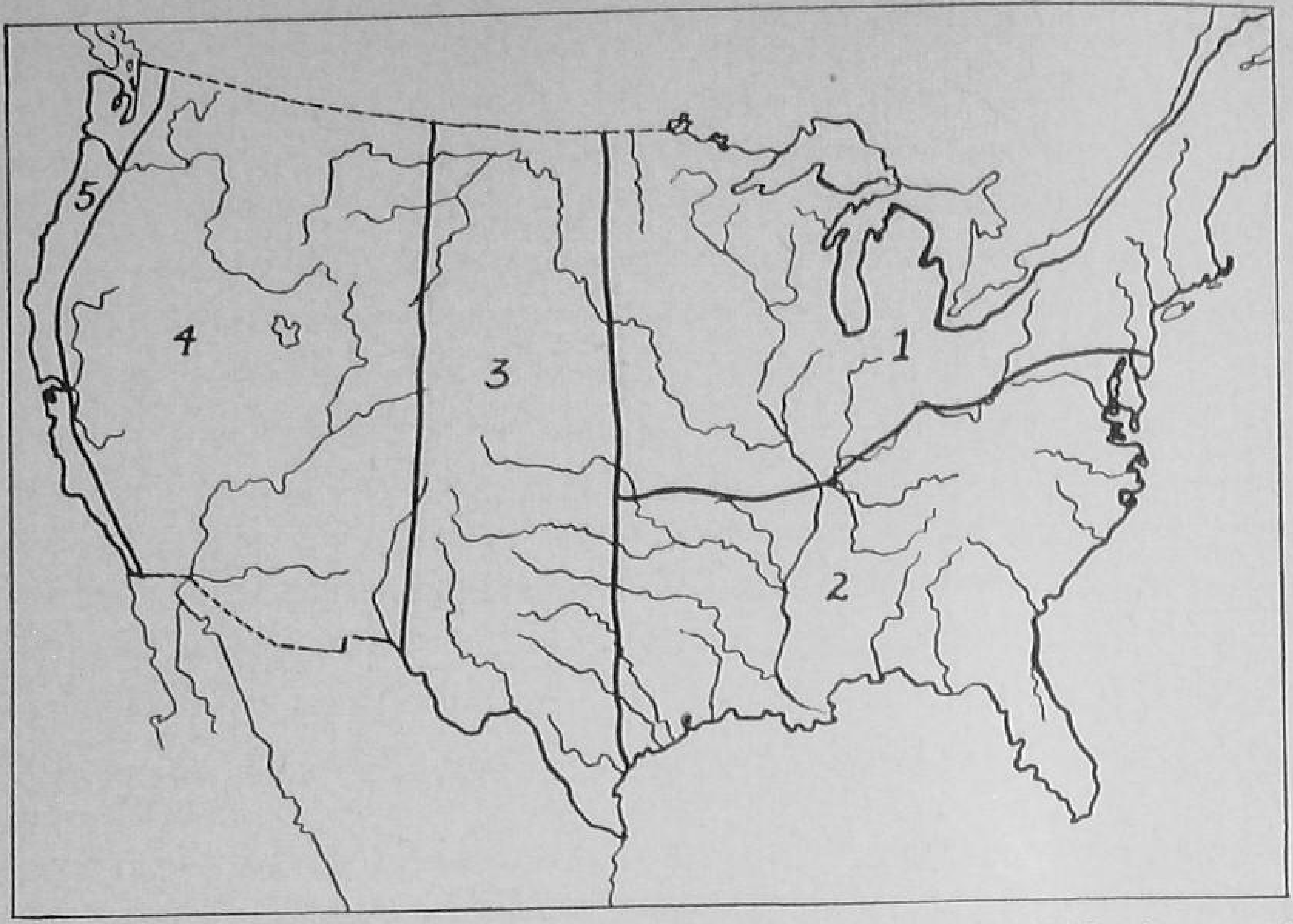


Fig. 51. Climates of the United States. (1) Cool-humid of Northeast and Great Lakes. (2) Warm-humid of Southeast and Gulf Coast. (3) Sub-humid of Great Plains. (4) Arid of Intermountain region. (5) Summer-dry of the Pacific Coast.

150 days in Long Island, New York. The annual rainfall varies from 30 to 40 inches, and the photoperiod of the summer is very long and that of the winter is very short. Although summer temperatures sometimes reach a maximum of 90° to 95° F., in general, they are sufficiently cool to permit the successful production of practically all hardy deciduous tree fruits and practically all cool-season vegetable and flower crops. At the same time, the temperatures are sufficiently high to permit the successful production of certain warm-season vegetable and flower crops. For example, the summer temperatures provide sufficient heat for the growing of certain varieties of tomatoes and beans; yet at the same time they fail to provide sufficient heat for the growing of sweetpotatoes and late maturing varieties of watermelons. The winter temperatures are relatively low, frequently reaching a minimum of minus 10° F. These temperatures often damage trees of the deciduous fruit industries and limit the growing of vegetables and flowers to greenhouses during the winter months.

Climate of the Southeast and Gulf Coast Region. The climate of this region is characterized by long warm summers, short mild winters, moderate

to heavy rainfall, and high light intensity. The frost-free growing period varies from 180 days in the mountains of North Carolina to 320 days in southern Florida. The annual rainfall varies from 45 to 80 inches, and the photoperiod of the summer is moderately long and that of the winter is moderately short. In this region temperatures are quite variable. In the elevated section of the northern part, summer temperatures are sufficiently cool to permit the successful production of hardy deciduous tree fruits and cool-season vegetable and flower crops; and in the southern part, they are sufficiently high to permit the successful production of warm-season plants such as: orange, lemon, grapefruit, lime, persimmon, avocado, fig, pecan, sweetpotato, watermelon, okra, camellia, azalea, and gardenia. Winter temperatures vary from a mean minimum of 10° F. in the elevated sections to 50° F. in southern Florida and the regions bordering the Gulf Coast. In fact, the temperatures of the coastal areas are sufficiently mild to permit the successful production of most cool-season vegetable crops during the fall, winter, and early spring. Most of the winter garden areas of the United States are located on the South Atlantic and Gulf Coasts.

Climate of the Great Plains Region. This climate is characterized by wide fluctuation in temperature, low rainfall, and high light intensity. The frost-free growing season varies from 109 days in central North Dakota to 314 days in south Texas. Although summer temperatures in the northern section are frequently as hot as those in the southern section, winter temperatures in the northern section are particularly severe, frequently reaching a minimum of minus 30° F., while in the Gulf Coast region of Texas they are particularly mild. In general, the average rainfall varies from 15 to 20 inches. Thus, since rainfall does not exceed evaporation, applications of irrigation water to most horticultural crops are necessary. The short frost-free growing period and the severe winter temperature in the northern section decidedly limits the production of warm-season vegetables and flowers and the production of tree fruits, since only the most hardy kinds will survive in this area. On the other hand, the long frost-free growing season and the mild winter temperature of the southern section permits the production of a great variety of horticultural products —strawberries in Oklahoma; tomatoes, sweetpotatoes, and rose stocks in east Texas; onions, spinach, and carrots in the winter garden region of south Texas; and grapefruit, cabbage, and tomatoes in the Rio Grande Valley.

Climate of the Intermountain Region. Here the climate is characterized by variable temperatures, low rainfall, and high light intensity. The tem-

peratures of the southern section are relatively high, and the frost-free growing period varies from 250 to 280 days. In the remainder of the region temperatures are relatively low and the frost-free growing period varies from 80 to 180 days. This wide variation in frost-free growing period is due largely to differences in latitude and to the wide variations in elevation throughout the region. The annual rainfall varies from 10 to 20 inches. Because of the low precipitation, all horticultural crops grown in this region, with the exception of dry land beans and peas, are irrigated. Moist winds from the Pacific Ocean are forced up the mountains and usually spill their load on the western slopes. This occurs at each successive range eastward. This precipitation is held as snow and is released later to supply the needs of the various crops. The low relative humidity is unfavorable for the development of foliage diseases; thus, many crops for seed are grown in this region.

Climate of the Pacific Coast Region. The climate of the Pacific Coast is characterized by comparatively cool summer temperatures along the coast, usually between the shore line and the coastal range, and high summer temperatures in the intermountain valleys, and by comparatively mild winter temperatures throughout the region. The average summer rainfall (June, July, and August) varies from 8 inches for the Puget Sound area to practically no rain for southern California, and the average winter rainfall (December, January, and February) varies from 50 inches for the Puget Sound area to 10 inches for southern California. Because of the mild winters, the relatively long frost-free growing period (from 200 days for the Puget Sound area to 320 days for southern California), and the abundant sunshine, a large number of horticultural industries are located in this region. Large quantities of citrus fruits and large quantities of a wide variety of vegetables are raised in southern California; large quantities of Vinifera grapes and peaches are raised in central California; and large quantities of apples are raised in Washington, Oregon, and northern California. The practically rainless summers are favorable for a high rate of photosynthesis and for the natural drying of a large number of horticultural products—prunes, grapes (raisins), peaches, apricots, apples, pears, figs, dates, and seed of many vegetable and flowering plants.

Within these climatic regions there are marked differences in the temperature of the growing season. The differences are due primarily to: (1) Differences in elevation and (2) proximity to large bodies of water.

Influence of Elevation. The altitude of the surface of the land above sea level has marked effects on the temperature. In general, for each 300 feet

in elevation there is an average decrease of 1° F. Thus, with an elevation of 4000 feet a decrease of about 13° F. is obtained. These differences in elevation within any particular region are chiefly responsible for differences in the length of the frost-free growing period and the maximum temperatures that occur. For example, at Clemson, South Carolina, the elevation is 774 feet; at Highlands, North Carolina, 50 miles west of Clemson, the elevation is 4500 feet. These differences in elevation make for marked differences in temperature between the two places. At Clemson the length of the frost-free growing period is 215 days and the summer temperature is sufficiently high to permit the successful production of long-season, warm-temperature crops such as the sweetpotato, but it is disastrous for the growing of cool-season crops such as cabbage, potato, or garden pea. On the other hand, at Highlands the length of the frost-free growing period is 178 days and the summer temperature is favorable for the production of the cool-season crops such as cabbage and the potato, but it is too low for the growing of warm-season crops, such as the sweetpotato.

Influence of Large Bodies of Water. Large bodies of water modify the temperatures of any one season. In the summer the water absorbs heat, thus decreasing the air temperature; and in the winter the water gives off heat, thus increasing the air temperature. As a result, the climate of maritime lands is more moderate and fluctuations in temperature are less wide than the climate of inland sections.

Large bodies of water within and surrounding the United States make possible the growing of certain horticultural crops which would not exist otherwise. The modifying influence of the Atlantic Ocean is partially responsible for the existence of the winter garden areas of the South; the modifying influence of the Great Lakes makes possible the growing of peaches and grapes in southern Michigan and western New York; and the modifying influence of the Pacific Ocean makes possible the growing of garden peas in the Puget Sound district of Washington and the growing of lima beans, lettuce, and other crops in the coastal regions of California. Many other examples could be cited.

SITES

Sites include two factors: (1) Topography and (2) soil. In horticulture, topography refers to the contour of the land, its elevation or depth, and similar features of the terrain. As previously stated, the soil is the home of the plant's roots and the reservoir for the plant's nutrients and water.

Kinds of Sites. In general, sites are: (1) Level or slightly sloped and

(2) sloped. Factors concerned in the selection of the site are: (1) Kind of crop enterprise, (2) kind and degree of soil erosion, (3) air drainage, and (4) exposure.

Kind of Crop Enterprise. In general, vegetable crops and herbaceous flowering plants are grown on level and slightly sloped sites. Most vegetable and flower crops require cultivation of the land, and harvesting operations can be performed more efficiently on level land than on sloped land. On the other hand, deciduous and evergreen tree fruits are grown on sloped land. With these crops air drainage requires more consideration than it does for herbaceous crops. Note the contour lines of the young peach orchard in Figure 52, and the straight rows and the level land of the field in Figure 53.

Soil Erosion. In the United States, soil erosion is a serious problem. In fact, many scientists believe that soil erosion is more responsible for the losses in soil fertility than any other single factor. Clearly, soil erosion should be reduced to a minimum. Two types are considered: (1) Erosion by wind and (2) erosion by water.

Erosion by Wind. This is severe on all soils in the Great Plains region

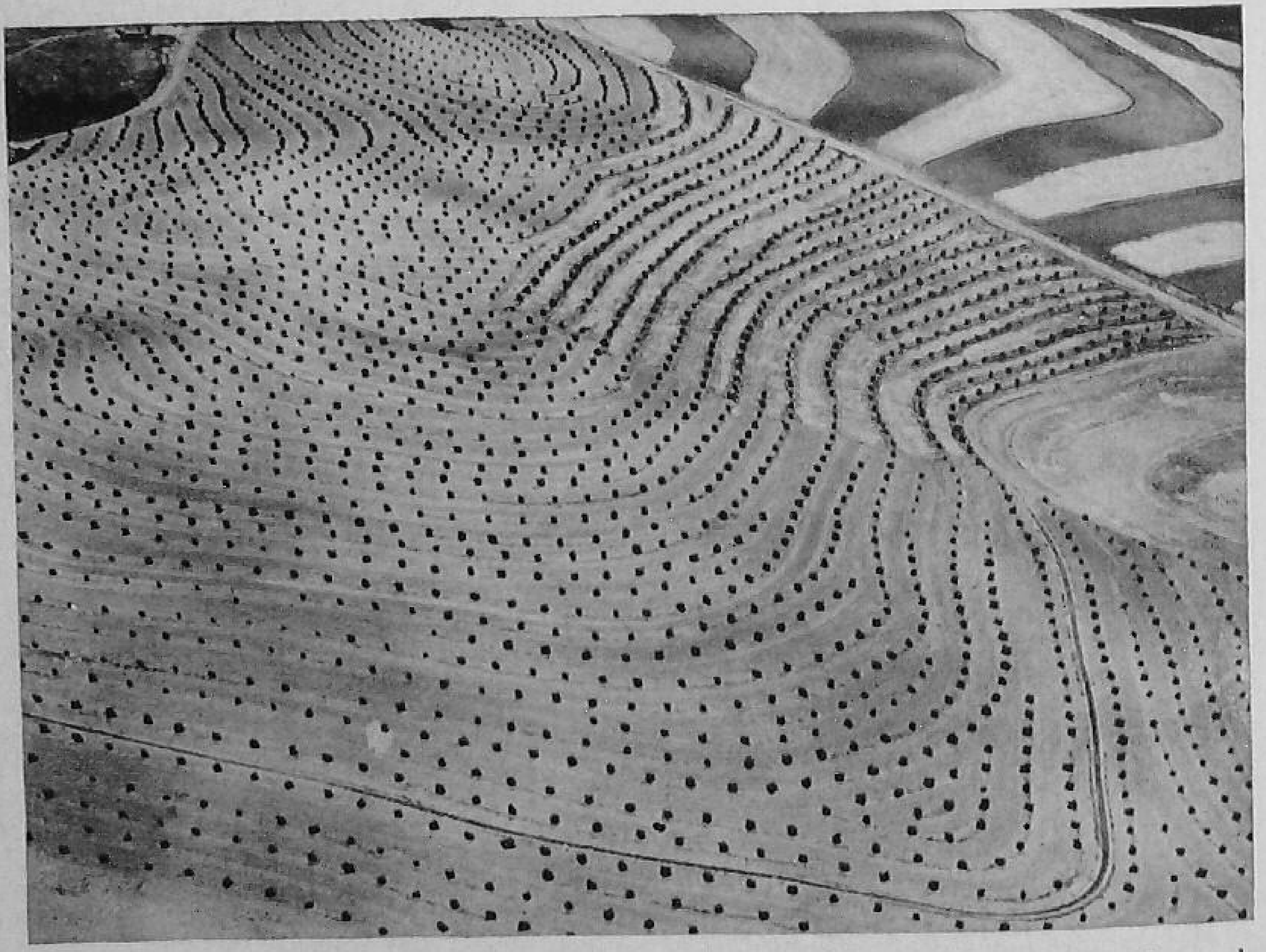


Fig. 52. A peach orchard in the Spartanburg-Inman district planted on the contour. (Courtesy, John T. Bregger, Soil Conservation Service, U.S. Department of Agriculture.)

Fig. 53. Part of a 640-acre field of celery in 1949, near Belle Glade, Florida. The narrow rows are 24 inches apart and the wide rows are 48 inches. The wide rows are necessary to accommodate the wheels of the spray rig. In this field the height of the water table is controlled to maintain adequate supplies of water. (Courtesy, J. C. Hoffman, Vegetable Breeding Laboratory, U.S. Department of Agriculture.)

and moderately severe on mucks and sandy soils in the Midwest and Northeast regions. Since the carrying power of the wind is a function of its velocity, decreases in velocity will correspondingly decrease the erosive action. In general, this is done by growing cover crops and by using wind breaks. Types of wind breaks are: (1) Trees, (2) shrubs, (3) fences of boards, slats, or cloth, and (4) the growing of strips of grain or forage crops.

Erosion by Water. This is severe in the humid regions, particularly in areas of high rainfall. As with the action of the wind, the carrying capacity of water is a function of its velocity. Thus, a decrease in the rate of water flow will correspondingly decrease the erosive action. In general, this is done by: (1) Terracing the land, (2) contour planting, (3) strip cropping, and (4) growing cover crops.

terracing the land. This consists of following the contours of the land and dividing the area into separate drainage systems. The function of each terrace is to reduce the rate of flow of water and to hold the water within each drainage area. This allows the water which has fallen within any given area to gradually soak into the soil. Broad, relatively flat terraces are most commonly used.

contour planting. Contour planting consists of planting crops with the contour. In this way, the cultivation of a particular row is done on level land rather than up and down or at right angles to the slope. Contour

tillage retards erosion by holding water in the small terrace made by the cultivator.

STRIP CROPPING. Strip cropping consists of the alternate planting of cultivated and non-cultivated crops in narrow or broad strips with the contour of the land. The non-cultivated crop absorbs the water falling on the non-cultivated area and the run-off from the adjacent cultivated area. Thus, soil erosion is reduced. The width of each cultivated or non-cultivated strip is determined by the steepness of the slope, the rate of percolation of water through the soil, the water-holding capacity of the soil, and the amount and character of the rainfall. Obviously, the steeper the slope, the lesser the rate of percolation and water-holding capacity, and the greater the rainfall, the narrower are the cultivated and non-cultivated strips.

GROWING COVER CROPS. Growing cover crops reduces soil erosion by holding the soil particles and by increasing the rate of percolation and the water-holding capacity of the soil.

Air Drainage. Air drainage involves the flow of air from areas of high elevation to areas of low elevation. Cold air flows from the high lands—the hills and mountains—into the low lands—the valleys. How does this flow of air take place? During the night radiation takes place which cools the earth's surface. This in turn cools the layer of air next to the soil, and since cold air is heavier than warm air, the cold air flows downward and the warm air flows upward. This phenomenon is called *temperature inversion* and when it occurs the high lands are warmer than the low lands.

For the successful production of the many tree fruits, adequate air drainage is particularly necessary. The cold air must be carried away from the immediate vicinity of the orchard, particularly during the blossoming season. Frequently during the period of flowering, the temperature of the cold air is from 1° to 5° F. below the killing temperature of the flowers and buds. At the same time the temperature of the warm air is from 1° to 5° F. higher. In many orchards, observations have shown differences of from 15° to 20° F. between the top and bottom of moderate slopes, and that variations in temperature much less than these often mean the difference between live and dead trees. In general, the higher the land in relation to adjacent areas, the greater the area of low land which receives the cold air, and the greater the freedom of air flow, the greater will be the freedom from injury. Thus, before orchards are planted, the frost hazard of proposed sites is carefully evaluated.

Exposure. Exposure refers to the direction of the slope. In general, a

southern or eastern slope: (1) Promotes early blooming and early maturity of the crop, (2) offers some protection against north or west winds, and (3) permits early planting of herbaceous crops. On the other hand, a northern slope: (1) Delays blooming of orchard trees and (2) offers some protection against sunscald in regions of high light intensity.

SOILS

Two important components of soils are: (1) Decomposed mineral matter and (2) decomposed organic matter. Soils which are derived from and contain large quantities of mineral matter are called mineral soils. Soils which are derived from and contain large quantities of organic matter are called muck or peat soils. Of these, mineral soils have the wider adaptation and distribution.

Mineral Soils*

Mineral soils consist of mixtures of sand, silt, and clay. Sand particles are relatively large (from 0.15 to 1.0 millimeter in diameter); silt particles are small (from 0.002 to 0.05 millimeter); and clay particles are very small (from 0.0001 to 0.002 millimeter). In fact, mineral soils can be classified according to the proportion of sand, silt, and clay which they contain. Principal classes are: (1) Sands, (2) sandy loams, (3) loams, (4) silt loams, and (5) clay loams. In horticultural crop production, each class has advantages and disadvantages.

Sands. In general, sands are coarse textured, well drained, relatively infertile, and very acid. They contain 80 to 95 per cent sand and 5 to 20 per cent silt and clay with 0.1 to 1.0 per cent organic matter. The large proportion of sand facilitates rapid drainage, aeration, and rapid decomposition of organic matter. On the other hand, the low proportion of silt and clay and the low content of organic matter provide for relatively small quantities of available water and small quantities of potential nitrate-nitrogen. In addition many sands are deficient in certain nutrient elements, particularly calcium and magnesium. Thus, the crop-producing capacity of sands is increased largely by reducing acidity, adding deficient nutrients, and increasing the organic matter. Despite the relatively low fertility of sands, with good management, they produce satisfactory crops such as peach, raspberry, asparagus, sweetpotato, and watermelon.

Sandy Loams. In general, sandy loams are moderately coarse textured, well drained, moderately fertile, and moderately to slightly acid. They con-

*This discussion is limited to soils in the humid regions. Since the amount of organic matter in mineral soils varies greatly, some soils naturally fall outside of the ranges of organic matter which are presented.

tain 50 to 80 per cent sand and 20 to 50 per cent silt and clay with 0.1 to 4.0 per cent organic matter. This proportion of sand is sufficient to permit rapid drainage, abundant aeration, and a moderately rapid oxidation of organic matter. At the same time, the proportion of silt and clay and the higher content of organic matter provide for a moderately high water-holding capacity and fairly high quantities of potential nitrate-nitrogen. Despite the somewhat high fertility of sandy loams as compared to sands, the crop-producing capacity is increased in much the same way as that of the sands, by reducing acidity, applying sufficient nutrients, and maintaining adequate supplies of organic matter. Sandy loams have a much wider adaptation than sands. Most ornamental plants, small fruits, peaches, plums, nuts, market garden crops near large centers of population, and truck crops grown in the winter garden areas of the South thrive well on these soils.

Loams. In general, loams are moderately fine textured, moderately well drained, moderately fertile, and moderately to slightly acid. They contain 30 to 50 per cent sand and 50 to 70 per cent silt and clay with 1.0 to 4.0 per cent organic matter. As compared to sandy loams their lesser proportion of sand and greater proportion of silt and clay combined with their greater organic matter content permit moderately rapid drainage, fairly abundant aeration, a moderately rapid oxidation of organic matter, and a moderately high water-holding capacity and nitrate-nitrogen supply. In general, loams have practically the same crop adaptation as sandy loams.

Silt Loams. In general, silt loams are fine textured, fairly well drained, fertile, and slightly acid. They contain 20 to 30 per cent sand and 70 to 80 per cent silt and clay with 1.0 to 6.0 per cent organic matter. This greater proportion of silt and clay permits moderately slow drainage, fair aeration, and a moderately slow oxidation of organic matter. The greater amount of organic matter provides for a high amount of available water and an abundant supply of potential nitrate-nitrogen. In these soils the maintenance of good tilth is more difficult than in loams and sandy loams. In marked contrast to the sands and sandy loams, the crop-producing power of silt loams is increased by improving the drainage and aeration.

Clay Loams. In general, clay loams are very fine textured, poorly drained, fertile, slightly acid, and slightly alkaline. They contain 20 to 50 per cent sand, 20 to 60 per cent silt, and 20 to 30 per cent clay with 1.0 to 8.0 per cent organic matter. This large proportion of silt and clay markedly decreases aeration and drainage, and the large amount of organic matter provides for a large amount of available water and potential nitrate-

nitrogen. As with silt loams, the maintenance of good tilth is difficult, and the crop-producing capacity is increased by drainage and aeration. Figure 54 shows the proportion of the soil separates in each of six classes.

Like the other types of soils, silt and clay loams have their place in crop production. In general, they are adapted to crops where large yields are more important than early yields. For example, most tomatoes and sweet corn for the cannery are grown on silt and clay loams. On the other hand, silt and clay loams are not well adapted to crops grown for their fleshy roots, or to tree fruits, unless the subsoil is well drained and permits deep and extensive penetration of the root system.

Soil Layers. A downward section of mineral soils shows distinct layers or horizons. These layers are called the topsoil, the subsoil, and the substratum. Of these the topsoil is more fertile, more subject to weathering and tillage operations, and, usually, more porous and better aerated. Soil organisms are therefore more abundant in this layer. The lower layers usually have a finer texture and a more compact structure. In some sections the subsoil becomes very compact, forming an impermeable layer called "hardpan" which retards drainage and resists root penetration.

The texture and acidity of the subsoil has an important bearing on the depth and penetration of the root system and the ability of plants to with-

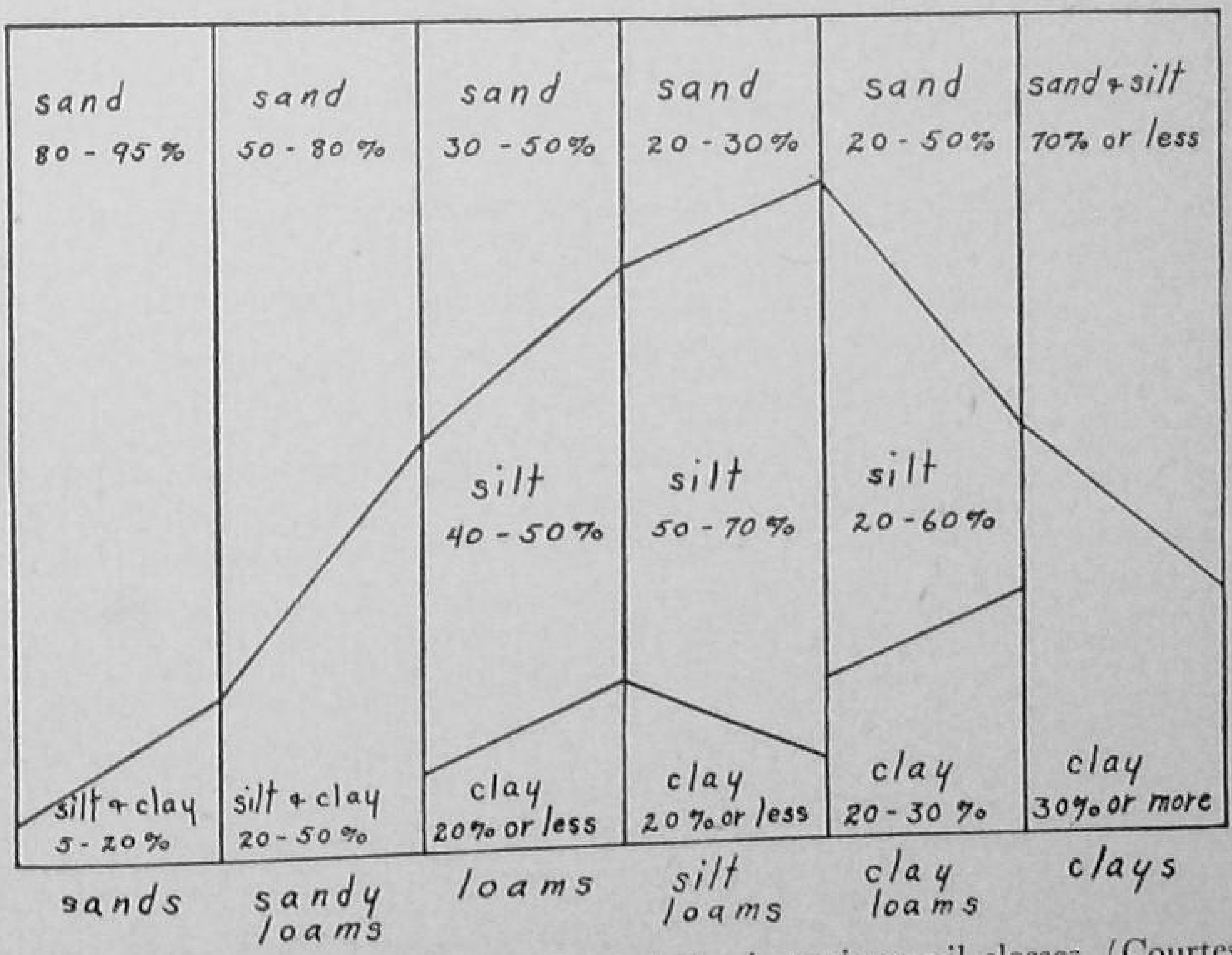


Fig. 54. The proportion of sand, silt, and clay in various soil classes. (Courtesy, Jackson B. Hester, Campbell Soup Company.)

stand drought. As previously stated, plants with deep root systems can obtain water and nutrients in the lower levels of the soil. In this way, the plants possess the capacity to withstand drought during hot weather, particularly when the transpiration rate is high. Tight, impervious subsoils resist root penetration and highly acid subsoils are unfavorable to root growth. In many areas subsoils are limed in order to make them more favorable for the growth and deep penetration of the roots.

Muck or Peat Soils

Muck or peat soils are composed of partially or highly decomposed plant remains which have accumulated through the ages in low wet places and contain from 20 to 80 per cent organic matter. If the soil has a fine texture and the plant remains are in an advanced state of decomposition, it is called muck. On the other hand, if the vegetable remains are still coarse and fibrous so that they mat together, the soil is called peat. Of these, mucks are more valuable for horticultural crop production. They are classified according to their acidity or lime content. There are three kinds: (1) Strongly acid or low lime, (2) moderately to slightly acid or high lime, and (3) alkaline.

Low Lime Mucks. In general, low lime mucks are strongly acid (pH 3.0–5.5). Because of this high acidity, comparatively few horticultural crops are adapted to them. Examples are cranberry and blueberry. Cranberries are grown extensively on the muck soils of New Jersey and Wisconsin.

High Lime Mucks. High lime mucks are moderately to slightly acid (pH 5.5–6.8). In sharp contrast to the low lime mucks, the acidity of these mucks is within the optimum reaction range for the growth of many horticultural crops. Examples are: celery, onion, cabbage, lettuce, and carrot. In fact, most of the commercial crops of onions and celery grown in New York and Michigan are produced on these so-called high lime mucks.

For any particular crop the management of mucks differs greatly from that of mineral soils. In general, mucks require packing when prepared for planting, maintenance of the water table close to the surface, application of large quantities of potash, and protection from wind erosion. Packing of the soil is necessary to close air spaces in the muck and to facilitate capillary action. The high water table, usually kept within 2 to 4 feet from the surface, is necessary to supply the plants with adequate water, to help prevent injury from summer frost in northern climates, and to reduce

wind erosion. Applications of large quantities of potash are necessary, since muck soils are notably deficient in potassium. Mixtures frequently used are 0–8–24, 0–10–20, 2–8–16, 3–9–18, and 3–12–12.

Alkaline Mucks. As the name suggests, alkaline mucks are alkaline in reaction (pH 7.1–8.2). Because of this alkalinity, these mucks are generally unadapted to the growing of horticultural crops. In some instances, slightly alkaline mucks have been made productive by applications of flowers of sulfur.

In general, peat is used for mulching ornamental trees and shrubs, for the growing of crops in the greenhouse, and in shipping herbaceous and ornamental plants.

Questions

1. From the horticultural standpoint, state briefly the advantages and limitations of each of the climatic regions.
2. Given one acre of land in the Northeast and Southeast respectively, with soil of moderate fertility in each region and supplied with optimum water and nutrients. In your opinion, which acre would produce the greater quantity of photosynthetic products for any given year? Give reasons.
3. Florida and California are important horticultural states. Explain.
4. How do large bodies of water influence the climate of the immediate vicinity?
5. Many horticultural industries are centralized within definite areas or belts. Explain.
6. A sloped topography is most desirable for tree fruits. Explain.
7. For fruit trees a northern slope may be more desirable in one section of the country and a southern slope more desirable in another. Explain.
8. Level sites are generally used for vegetable and flower crops. Explain.
9. What is the main difference between sand and silt?
10. Soils made up of fine particles such as silt hold more available water than soils made up of coarse particles such as sand. Explain.
11. Given two soils. Soil A, a coarse sandy loam, and soil B, a silt loam. Which can be safely cultivated sooner after a rain? State your reasons.
12. On which type of soil, a sandy loam or a clay loam, would a plant come into the reproductive type of growth earlier? Explain.
13. What type of soil is best adapted to vegetables grown for early market? For vegetables grown for canning? Explain.
14. In general, what class of soils has the wider adaptation for horticultural crops?
15. Topsoil is more fertile than subsoil. Explain.
16. The texture of the subsoil is of particular importance to the grower of tree fruits. Explain.

17. State the composition of muck soils.
18. What properties do muck soils and the heavy loams have in common?
19. What properties do muck soils and the lighter loams have in common?
20. Onions, lettuce, celery, cabbage, and carrots thrive exceptionally well on slightly acid muck soils. What reasons can you offer to explain the response of these crops?

9

Organic Matter

Assignment 14

Organic matter in mineral soil consists of a heterogeneous mass of many organic compounds. These compounds are decomposed by soil organisms and are either completely oxidized to carbon dioxide, water, ammonia, and other simple substances with the liberation of heat and other forms of energy or are changed to humus. In general, the simple, easily decomposed compounds such as simple proteins, starch, hemicellulose, and sugar are completely oxidized; and the complex, difficultly decomposed compounds such as lignin and complex proteins are changed to humus. Thus, soil organic matter has two components: (1) Organic matter under the process of decomposition and (2) humus. Both components markedly influence the fertility of soils and the growth of plants.

THE DECOMPOSITION OF ORGANIC MATTER

Soils are dynamic; they teem with life. Vast numbers of microörganisms live in the soil. These organisms must have a source of energy for their vital needs. Many kinds obtain their energy requirements by decomposing organic matter. This decomposition is biochemical and is illustrated as follows: (note that both water and oxygen are necessary for the reaction).

$$\text{Organic matter} + H_2O + O_2 \xrightarrow{\text{(soil organisms)}} CO_2 + H_2O + NH_3 + H_2S + \text{other gases} + \text{energy}$$

Many components of the soil environment influence the rate of decomposition. Principal components are: (1) Temperature, (2) moisture, (3) aeration, and (4) reaction.

Soil Temperature. The rate of respiration of soil organisms and the consequent rate of decomposition of organic matter follows rather closely the van't Hoff law. This law states that for every increase of 10° C. from 0° to 35° C. the rate of a process is doubled or trebled. Thus, the rate of decomposition of organic matter will be at least twice as rapid at 30° C. (86° F.) as at 20° C. (68° F.). How can this effect of temperature be applied to the rate of decomposition of organic matter in various parts of the country? Since for any particular season higher temperatures exist in warm climates than in cool climates, the rate of decomposition will be greater in the warm regions. Numerous investigations have shown this to be the case. Consequently, applications of organic matter in warm climates should be more frequent than in cool climates, and in the same climate they should be more frequent in greenhouses than outdoors.

Soil Moisture. Soil organisms require water for their growth and activities—for cell division, for the making of protoplasm, and for the utilization of necessary nutrients, such as nitrates and phosphates. Thus, with other factors in favorable supply, organic matter decomposes more rapidly in moist soil than in dry soil.

Soil Aeration. As previously stated, the decomposition of organic matter requires atmospheric oxygen. The ammonifiers require oxygen to change proteins to ammonia; the nitrifiers require oxygen to change ammonia to nitrites and finally to nitrates; and the sulfur bacteria require oxygen to change sulfur to sulfites and finally to sulfates. The oxygen is a component of soil air and this air, together with water, occupies the pore space of the soil. If the pore space is full of water, that is, if the soil is saturated, soil air and oxygen are lacking and the activity of the ammonifiers, nitrifiers, and sulfur bacteria is correspondingly low. In general, moist soils have adequate quantities of both water and oxygen.

Soil Reaction. As previously stated, soil reaction refers to the degree of acidity. In general, soils may be very acid, moderately acid, slightly acid, or slightly alkaline. As stated in Chapter 6, the degree of acidity of the soil solution markedly influences the growth and activity of many kinds of soil organisms. For example, the ammonifiers and nitrifiers are more active and abundant in moderately and slightly acid soils than in strongly acid or strongly alkaline soils. Thus, with other factors favorable, the rate of decomposition is most rapid in moderately or slightly acid soils.

NATURE AND VALUE OF HUMUS

When organic matter is incorporated with soil, its ratio of nitrogen to carbon is usually wide. As decomposition proceeds, relatively large quantities of carbon dioxide are liberated, and relatively small amounts of ammonium-nitrogen and nitrate-nitrogen are formed. This decomposition continues until the ratio of nitrogen and carbon is approximately in the proportion of 1 to 10.* When this ratio has been attained, further decomposition consists of parallel rates of nitrogen and carbon. In other words, humus in its final state of decomposition has a ratio of 1 part of nitrogen to 10 parts of carbon. Humus is important in connection with: (1) Holding of bases, (2) phosphate availability, (3) aluminum toxicity, (4) holding of water, and (5) aeration.

Base-holding Power. Humus possesses the ability to hold bases. This base-holding ability is due largely to the large number of negative charges surrounding each humus particle. Thus, humus reacts and combines with positively charged ions in the soil solution. Some of these ions can be exchanged with one another and do not greatly change the nature of the humus. Others react with humus and form stable colloids. Ions which are exchanged are Ca^{++}, Mg^{++}, K^{+}, Na^{+}, and H^{+}. Ions which are not exchanged and which form stable colloids are Al^{+++}, Fe^{+++}, and Mn^{++}. Thus, the base exchange capacity of humus varies indirectly with the soluble iron and aluminum content of soils. Humus of soils high in aluminum or iron will have a low base exchange capacity. Conversely, humus of soils low in aluminum and iron will have a high base exchange capacity.

Phosphate Availability. Humus fixes phosphate ions in a loose chemical state. These phosphate ions are available to the plant. Thus, with other factors favorable for growth, soils high in humus contain greater quantities of available phosphorus than soils low in humus. The ability of humus to fix phosphorus is particularly important on very acid soils. High acidity, less than pH 5.0, increases the solubility of iron and aluminum. These elements combine with the phosphate ion and form the unavailable iron and aluminum phosphate. Frequently, the amount of phosphorus applied to soils is much greater than that required by crops. For example, growers of potatoes in eastern Virginia apply from 600 to 750 pounds of superphosphate per acre each year. The crop itself needs only from 150 to 190 pounds. The remainder is fixed in an unavailable state by the soil. Experi-

*Some authorities state 1 to 12.

ments have shown that under the foregoing conditions organic matter reduces the amount of phosphate fertilizer that is combined in an unavailable state in very acid soils, and hence greater quantities are available for the crop. Organic matter, therefore, is beneficial for crops which for some reason or other require very acid* soil.

Aluminum Toxicity. When a relatively large concentration of aluminum ions exist in the soil solution, horticultural plants grow slowly and yield poorly. As stated previously, the concentration of these ions is dependent largely on the degree of acidity. In many soils aluminum ions begin to appear in toxic concentration when the pH is below 5.0. Studies at the Virginia Truck Station show that organic matter reduces the concentration of aluminum ions in very acid soils. For example, Norfolk fine sand at pH 5.0 with 1 per cent organic matter had 875 milligrams of Al_2O_3 per 1000 grams of soil, while the same soil with 5 per cent organic matter had only 0.2 milligram. Plants growing in the soil with 1 per cent organic matter failed to grow normally, while those growing in the soil with 5 per cent organic matter made satisfactory crops. Evidently, organic matter is very helpful in reducing or entirely preventing aluminum toxicity. Manifestly, the humus unites with the aluminum ions to form a relatively stable colloid. In this way toxic concentrations of aluminum ions are taken out of solution and rendered harmless to the plants.

Water-holding Capacity. The water-holding capacity of soil is closely related to its humus content. Humus is a colloidal complex, hydrophilic and extremely porous. Each colloidal particle absorbs large quantities of water, most of which is available to plants. The ability to hold water and the enormous internal surface of humus combine to raise the water-holding capacity of soils to a marked degree. For example, tests have shown that humus has four times the water-holding capacity of clay and eight times the water-holding capacity of sand. Thus, soils high in organic matter have a higher water-holding capacity than soils low in organic matter.

Aeration. Aeration refers to the amount of air in the soil. As stated in Chapter 3, the air and water of a soil occupy the space between the particles. If a soil is fully saturated no air is present; hence the quantity of air in the soil is inversely proportional to the water content. The principal gases of soil air are nitrogen, oxygen, and carbon dioxide. In general, this air is comparatively high in carbon dioxide (0.5 to 10.0 per cent) and low

*In the potato belt of eastern Virginia, the soils are kept at pH 5.0 to 5.5 because of the presence of scab.

in oxygen (10.0 to 19.0 per cent). The oxygen supply must be constantly renewed since root systems and soil organisms require abundant oxygen for water absorption and for respiration. Tests have shown that organic matter increases the pore space of soils, and hence it increases the aeration capacity of soils. Thus, mineral soils high in organic matter have a greater aerative capacity than soils low in organic matter.

The Nitrogen:Carbon Ratio

The nitrogen:carbon (N:C) ratio of organic matter has an important bearing on the humus content of mineral soils. Suppose two crops of the same tonnage but with different ratios are turned under. Lot A has a ratio of 1:80 and lot B has a ratio of 1:20. Which lot will add the greater amount of humus? Since the soil organisms will reduce each lot to the same ratio, about 1:10, they will decompose much more carbonaceous material in lot A than in lot B. (The carbon will disappear in the form of carbon dioxide.) Hence, lot B will add more humus to the soil than lot A, and in general, organic matter possessing narrow ratios will be more effective in building up the humus content of soils than material with wide ratios. A classification of organic matter based on the N:C ratio is shown

Table 19

Organic Matter of Various N:C Ratios*

Organic Matter High in N; High in C (*A Narrow Ratio*)	*Organic Matter High in N; Low in C* (*A Very Narrow Ratio*)	*Organic Matter Low in N; High in C* (*A Very Wide Ratio*)	*Organic Matter Low in N; Low in C* (*A Wide Ratio*)
Legumes (1:20) Non-legumes in early stages (1:20) Peat (1:20–1:30)	Liquid manure (1:10) Legumes in early stages of growth (1:15–1:20)	Straw (1:80) Stubble (1:80) Strawy manure (1:80) Leaves (1:80) Sawdust (1:400)	Rotted straw (1:60) Non-legumes in late stages of growth (1:60) Rotted leaves (1:60)

*Data from various sources.

in Table 19. Note that various types of organic matter possess different N:C ratios, and that the same crop has a narrow ratio at the early stages of growth and a wide ratio at the later stages. For example, rye has a 1:30 ratio in the immature stage and a 1:60 ratio in the mature stage.

Thus, much larger quantities of mature rye than of immature rye will be required to add a given amount of humus to soils.

Soil Organisms and Plant Growth. Soil organisms compete with higher plants for available nitrogen. In fact, soil scientists believe that the needs of soil organisms are met first. This ability of soil organisms to successfully compete with crop plants for available nitrogen may or may not be beneficial. If the plants are making slow growth due to an inadequate available nitrogen supply, the utilization of nitrate-nitrogen by soil organisms would be injurious. On the other hand, if the plants are making unduly vigorous vegetative growth because the available nitrogen is in excess, the utilization of the nitrogen by soil organisms would be beneficial. This behavior of soil organisms explains why symptoms of nitrogen deficiency occur on herbaceous crops which have been planted immediately after a mature green-manuring crop has been turned under; why mulching spring-planted herbaceous crops with straw is likely to retard vegetative growth and, in extreme cases, produce symptoms of nitrogen deficiency; why applications of sodium nitrate or ammonium sulfate will facilitate decomposition of mature green-manuring crops; and how vigorous vegetative growth in the orchard or vineyard can be slowed up in the

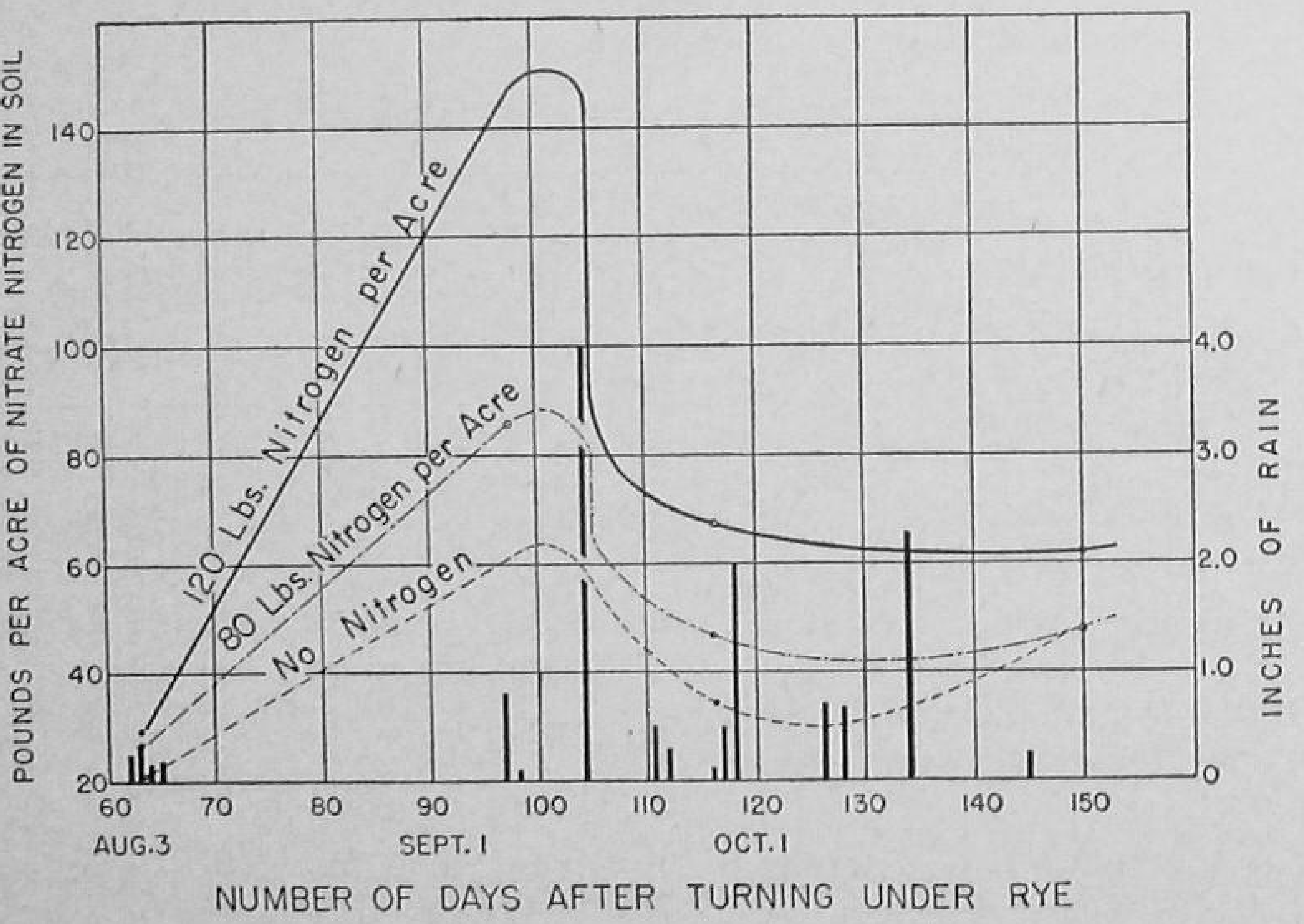


FIG. 55. The effect of applying available nitrogen to a green-manuring crop of mature rye on the formation of nitrates. Note the effect of the 4-inch rain on the leaching of nitrates. (Adapted from Fig. 248, *Va. Truck Exp. Sta. Bul. 94*, 1937.)

late summer or fall. Note the effect of available nitrogen on nitrate formation in Figure 55, and the effect of paper pots on the growth of tomatoes in Figure 56.

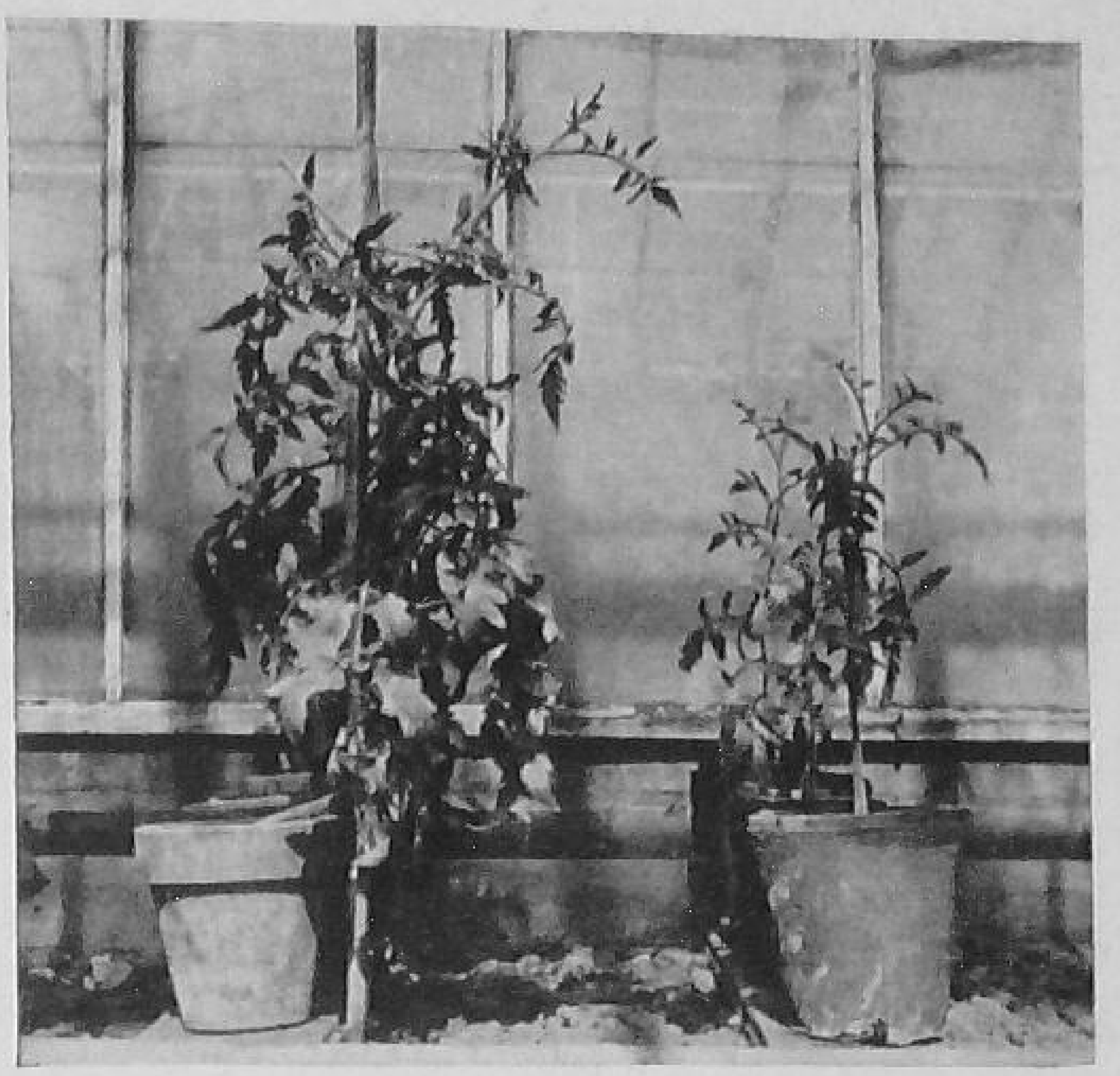


Fig. 56. Effect of organic matter with a wide ratio on the growth of tomato plants. (*Left*) Plants growing in clay pots. (*Right*) Plants growing in paper pots. The plants are of the same variety and were started at the same time.

Questions

1. Name the two components of organic matter.
2. What is humus?
3. Write the equation illustrating the decomposition of organic matter.
4. Organic matter decomposes more rapidly in warm-moist soils than in cool-wet soils. Give two reasons.
5. Organic matter decomposes more rapidly in southern United States than in northern United States. Explain.
6. Organic matter decomposes more rapidly in greenhouses and in hotbeds than outdoors. Explain.
7. If the soil is dry, rate of decomposition is slow. Explain.
8. The rate of decomposition of organic matter is faster in well-drained soils than in poorly drained soils. Explain.
9. The comparatively high rate of decomposition of organic matter in southern United States should be considered an asset rather than a liability. Explain.

10. When a farmer says, "The soil has burned itself out," just what does he mean?
11. State the two nutrient elements made available by the activity of soil organisms.
12. Plants growing in saturated soils eventually wilt. Explain.
13. How does humus make phosphorus more available?
14. How does humus reduce aluminum toxicity in very acid soils?
15. How does organic matter increase the water-holding capacity and aeration of soils?
16. A grower wished to plow under a layer of straw in the spring on a well-drained sandy loam. What would you advise?
17. Just before a mature green-manuring crop is plowed under, growers frequently apply from 100 to 200 pounds of sodium nitrate or ammonium sulfate per acre. Explain.
18. Straw and strawy manure are poor builders of soil humus. Explain.
19. Investigations at the Oklahoma Station have shown that potatoes planted immediately after the plowing under of a mature crop of rye showed symptoms of nitrogen deficiency. Explain.
20. Spinach grown on a soil immediately after the plowing under of a mature green-manuring crop is likely to show symptoms of nitrogen deficiency. Explain.

PRODUCTION OF ORGANIC MATTER

Before organic matter can be incorporated into soil it must be produced. Organic matter is produced by green plants. In general, it is incorporated in the soil in two forms: (1) As a crop or (2) as manure.

Growing of Crops

Crops grown for the special purpose of adding organic matter to soils are called soil-improving crops. These crops have two prime functions: (1) To provide a cover for the soil and (2) to add organic matter. In certain horticultural enterprises (for example, in the production of apples or peaches), such a crop may be grown primarily to provide a cover for the soil. In other enterprises (for example, in the growing of potatoes or cabbage), the crop may be grown primarily to add organic matter. Soil-improving crops grown primarily to serve as a soil cover are called cover crops, and those grown primarily to add organic matter are called green-manuring crops. The student should remember that both types of crops provide a cover for the soil and add organic matter. They are called cover crops or green-manuring crops according to the main purpose for which they are grown.

Uses of Soil-improving Crops Other than Supplying Organic Matter.

Uses of soil-improving crops other than supplying organic matter are: (1) Conserving the supply of certain nutrients, (2) reducing erosion, (3) checking vegetative growth of crop plants, and (4) retaining snow in cold climates.

Conserving Supplies of Certain Nutrients. The principal nutrients conserved are nitrate-nitrogen, phosphates, sulfates, calcium, magnesium, and potassium. Nitrate-nitrogen is conserved in the following manner: the crop absorbs the nitrates. In the plant these nitrates are changed to ammonium forms which combine with sugars to form proteins. These proteins are used for the making of protoplasm and reserve foods. Thus, the nitrogen in the absorbed nitrates becomes part of the plant body. When the soil-improving crop is turned under, decomposition sets in and the proteins are changed to nitrate-nitrogen by soil organisms. The conservation of nitrates is illustrated as follows:

$$\underset{\text{(in soil)}}{NO_3\text{—}N} \longrightarrow \underset{\left(\substack{\text{plant body}\\ \text{conservation}}\right)}{\text{Protein—N}} \longrightarrow \underset{\text{(in soil)}}{NH_3} \longrightarrow NO_3\text{—}N$$

The amount of nitrate-nitrogen conserved is quite marked. Lysimeter experiments at the West Virginia Station have shown that soils of orchards without a cover crop may lose as much as 100 pounds of nitrate-nitrogen per acre per year, and that the same soil with a cover crop may lose only 10 to 20 pounds per acre per year. Many other experiments could be cited. This conservation of nitrogen, therefore, results in considerable saving in the nitrogen supply.

Calcium, magnesium, and potassium are conserved when nitrates are conserved. The nitrate ion is negatively charged, is not held by soil colloids, and unites with positively charged minerals. In the soil these minerals are calcium, magnesium, and potassium. For every pound of nitrate-nitrogen leached, 0.7 pound of calcium, or 0.4 pound of magnesium, or 1.3 pounds of potassium, or equivalent parts of all three are also leached.

Phosphates and sulfates are conserved in much the same way as nitrates. The soil-improving crop absorbs phosphorus and sulfur in the form of phosphates and sulfates. In the plant, phosphorus and sulfur are used to make certain proteins. When the crop is turned under, the proteins containing phosphorus and sulfur decompose, and the phosphorus and sulfur are changed to phosphates and sulfates. Here again, the amount absorbed by soil-improving crops is quite marked. Investigations at the Virginia Truck Station have shown that a crop of sorghum yielding over 4 tons of

dry matter per acre absorbs about 20 pounds of phosphorus. This is more phosphorus than an acre of potatoes or other horticultural crop requires.

RETARDING EROSION. Soil-improving crops reduce erosion in the following manner: since the plants are grown close together, their roots ramify practically all of the topsoil and a considerable part of the subsoil. In this way the roots serve as a fine, interlacing network which holds the soil together. In other words, they bind the soil. In addition, soil-improving crops reduce the packing effect of heavy rains, check the flow of water, spread it, and filter it from its load of silt. Thus, these soil-improving crops not only increase the fertility of the soil but also hold the soil.

CHECKING VEGETATIVE GROWTH OF CROP PLANTS. Soil-improving crops are used as cover crops in the production of apples, pears, peaches, grapes, pecans, and citrus fruits. When soil-improving crops are planted during the latter part of the growing season, they check the growth of the crop plants. The cover crop absorbs the nitrates, minerals, and water which may otherwise be used by the crop. This reduction in the nutrient supply, or in the water supply, or in both reduces the rate of cell division. This reduction in the rate of cell division in turn correspondingly reduces the rate of carbohydrate utilization and facilitates carbohydrate accumulation. As stated previously, carbohydrate accumulation is necessary to make woody plants resistant to the adverse conditions of the winter and for the growth of the roots, flowers, leaves, and twigs the following spring. The planting of cover crops to check vegetative growth of trees in orchards and of vines in vineyards is a standard practice in the many producing districts of the country.

RETAINING SNOW IN COLD CLIMATES. In general, a blanket of snow in the orchards or vineyards in the northern part of the United States is distinctly beneficial. The layer of snow keeps the soil comparatively warm and, in this way, it protects the roots of orchard and vineyard plants from winter injury due to extremely low temperatures. Cover crops vary in their ability to hold snow. For example, in Michigan amber sorghum and Sudan grass have been found more satisfactory than oats, vetch, rape, soy bean, or buckwheat.

Selection of Soil-improving Crops. The selection of a soil-improving crop depends on many factors. Most important are: (1) Kind of crop, legume or non-legume, (2) adaptation to soil and climate, and (3) type of horticultural enterprise.

KIND OF CROP. As previously stated, soil humus consists of lignin and a complex protein. Consequently, crop components high in these materials

are more satisfactory as soil-improving crops than those comparatively low. In other words, crops which have comparatively narrow N:C ratios are better builders of soil organic matter than crops with comparatively wide ratios. In general, for the same state of maturity, legumes have narrow ratios and non-legumes have wide ratios. In addition, the growing of legumes is a means by which nitrogen can be supplied to soils and plants.

ADAPTATION TO SOIL AND CLIMATE. Soil-improving crops differ in their acidity and temperature requirements. Some crops thrive best in slightly acid soils only; others thrive best in both moderately acid and slightly acid soils. Some thrive best in warm weather; others thrive best in cool weather. A classification based on soil acidity and temperature requirements follows.

CROPS THRIVING WELL ON A WIDE RANGE OF ACIDITY (pH 5.0–7.0):

Cool Crops:

Legumes—crimson clover, vetch, Austrian winter pea, Caley pea, and Creole pea.

Non-legumes—rye, oats, rape, and buckwheat.

Warm Crops:

Legumes—cowpea, crotalaria, lupine, soy bean, velvet bean, and lespedeza.

Non-legumes—amber sorghum, Sudan grass, and millet.

CROPS THRIVING BEST ON A NARROW RANGE OF ACIDITY (pH 6.5–7.0):

Legumes—alfalfa, sweet clover, red clover, white clover, Ladino clover.

TYPE OF HORTICULTURAL ENTERPRISE. Practically all types of horticultural enterprises use soil-improving crops. For example, many tree fruits, such as apple, pear, peach, and citrus, are produced under the controlled-cover crop system of soil management. This system consists of growing a cover crop for a definite period, and keeping its growth under control. With the apple, pear, and peach the cover crop is disked or mowed in the spring and summer and another crop is started the following fall. Disking or mowing the cover crop in the spring and summer eliminates competition for water and nutrients. Cover crops used are: winter vetch, cowpea, rye, oats, Sudan grass, sorghum, millet, buckwheat, and turnip. With citrus in Florida the cover crop is grown in the summer, and clean cultivation is practiced during the winter. During the summer the rainfall is

sufficient for the growth of both the trees and the crop, but during the winter the rainfall usually is sufficient only for the growth of the trees. Cover crops used are: beggar weed, crotalaria, and bush velvet bean. Note the cover crop in the peach orchard in Figure 57.

Vegetable crops grown in the northern regions are produced in the summer and the soil-improving crop is started in the fall. For example, in the market garden district of Long Island, New York, potatoes, cauliflower, carrots, and other vegetables are planted in the spring and harvested in the fall. Rye or a mixture of rye and vetch is planted immediately after the crop is harvested and is plowed under in the spring. These soil-improving crops are particularly satisfactory in this district, since they grow well in cool weather and are adapted to moderately acid and slightly acid soils. On the other hand, vegetable crops produced in the winter garden areas in the southern regions are produced in the late fall, winter, and early spring, and the soil-improving crop is grown in the summer. For example, in the Mobile Bay truck crop district of southern Alabama, potatoes are produced in considerable quantity. The seed pieces are planted in February and the tubers are harvested in May and June. Crotalaria or some other warm-season crop is planted immediately after the potatoes are harvested and allowed to grow until the fall and early winter

Fig. 57. A cover crop of burr clover in a peach orchard of the Spartanburg-Inman district. (Courtesy, John T. Bregger, Soil Conservation Service, U.S. Department of Agriculture.)

There are two types of manure: (1) Animal manure and (2) artificial manure.

Animal Manure. Animal manure, just like organic matter, consists of a heterogeneous mass of organic compounds in various states of decomposition. Some of these compounds decompose quickly; others decompose slowly and finally change to humus. Thus, the application of manure supplies nutrients to soil organisms and crop plants. However, it is extremely low in nutrient content when compared to the commercial fertilizer mixtures on the market. For example, a ton of horse manure of average composition contains about 10 pounds of nitrogen, 5 pounds of phosphoric acid, and 10 pounds of potash. This has the analysis of 0.5 per cent nitrogen, 0.25 per cent phosphoric acid, and 0.5 per cent potash. Moreover, only about one half of the nitrogen, one sixth of the phosphoric acid, and one half of the potash is immediately available to plants. In addition, animal manure is not a balanced fertilizer since it is low in phosphorus.

Before the advent of the automobile industry, many growers of horticultural crops, particularly market gardeners near large cities, obtained large supplies of manure from the many livery stables. In fact, this manure was the only material used to supply the nutrient requirements of the crops. However, the development of the commercial fertilizer industry has enabled growers to depend less on manure and more on commercial fertilizers. Many experiments with vegetable crops have shown that applications of moderate amounts of manure (10 to 15 tons per acre), combined with the use of commercial fertilizers (500 to 1000 pounds per acre), have produced greater yields than the use of heavy applications of manure alone (20 to 40 tons per acre).

Artificial Manure. Artificial or synthetic manure consists of the decomposition of organic matter under more or less controlled conditions. Various types of organic matter may be used: straw, hay, cornstalks, weeds, lawn clippings, and leaves are examples. The organic matter is treated layer by layer with commercial fertilizers and lime, and may or may not be wetted down by artificial applications of water. As previously stated, organic matter is decomposed by fungi and bacteria. Many factors influence their activity. For the making of manure important factors are: (1) Nature of the plant material, (2) amount of available nitrogen and other fertilizer materials, (3) moisture supply, and (4) temperature. In general, crop residues high in nitrogen, or green material, or warm-moist material

will decompose more rapidly than residues low in nitrogen, or dry material, or cool-wet material, respectively. Of these factors, the water supply seems to be particularly important. In fact, experiments have indicated that the moisture supply seems to be a limiting factor more frequently than the temperature. For example, in June of 1933 two lots of straw were prepared for synthetic manure production at the Michigan Experiment Station. One lot, A, was wetted down at frequent intervals throughout the summer and the other lot, B, was wetted by the rain only. Lot A produced a well-decomposed lot of manure by November of the same year while lot B did not produce a satisfactory manure until July of the following summer. In other words, the annual rainfall of Michigan was sufficient to produce a good grade of synthetic manure in 12 months, and the addition of water produced manure in about 5 months. Thus, regions of comparatively high rainfall should facilitate more rapid decomposition than regions of low rainfall.

USE OF PEAT

The commercial florist is finding the use of peat advantageous in the production of certain greenhouse crops. As sold commercially, peat is a brown, spongy, semigranular material which is dry and easy to handle. It is comparatively free from disease pests and has a high water-holding capacity. Tests at the Ohio State University have shown that soils with peat as a mulch produced larger and better flowers of most greenhouse flower crops than soils without peat as a mulch. When peat was applied with suitable amounts of manure, 1 part to 20 by volume, it served as a very suitable material for the growing of flower crops in the greenhouse.

Questions

1. Soil-improving crops have many uses other than that of supplying organic matter. Explain.
2. Explain the mechanism of nitrate-nitrogen conservation.
3. On the basis of the West Virginia results, growers of apples could well afford to raise cover crops in their orchards. Explain.
4. How do cover crops reduce soil erosion?
5. Show how the grower can check vegetative growth of trees in the orchard or vineyard by the use of cover crops.
6. Cool-season cover crops which thrive on a wide range of acidity are well adapted for use in the apple orchard. Explain.

7. Rye is a popular cover crop among market gardeners in northern United States while soy beans, cowpeas, and crotalaria are popular among truck growers in southern United States. Explain.
8. Could weeds be used as a cover crop? Give your reasons.
9. In the southern regions a crop should be growing on a given area of land at all times. Explain.
10. Manure has greater value in supplying soil with humus than in supplying soil with nutrients. Explain.
11. The rate of synthetic manure production is dependent largely on the rainfall. Explain.
12. Your mother wants to know how to make leaf mold. Give her the necessary instructions.
13. A farmer has a large amount of straw at his disposal. Show how he may use this straw for synthetic manure production.
14. The organisms that decompose organic matter are extremely beneficial. Explain.

10

Commercial Fertilizers

Assignment 15

Commercial fertilizers are chemical compounds which are used to supply, either wholly or in part, the nutrient needs of crops. Some of these compounds contain nutrients which are readily available; others must undergo certain changes before the nutrients become available. Examples of the former are sodium nitrate and water-soluble and citrate-soluble calcium phosphate; examples of the latter are urea and cyanamide.

Commercial fertilizers are frequently called plant foods. In a strict sense they are not plant foods. *Foods are substances which supply both plants and animals with energy.* In general, these substances are the carbohydrates, proteins and fats, and related compounds. Since commercial fertilizers cannot supply plants with energy, they should not be classified as plant foods. In reality, commercial fertilizers are compounds which supply plants with nutrients. The green plant uses these nutrients, directly or indirectly, to make the all-important foods.

THE COMMERCIAL FERTILIZER INDUSTRY

The making of commercial fertilizers is an important chemical industry. In 1948 approximately 16 million tons of commercial fertilizers were used in the United States, and the total cost to growers was about 800 million dollars. Because of the bulky nature of commercial fertilizers and the necessity for minimizing transportation costs, most commercial fertilizer mixing plants are located in the principal regions of consumption. In the

United States the greatest consuming region is the Southeast. In this region considerable areas have been given over to the production of cash crops for a relatively long time; the soil is generally less fertile; and the intense rains cause excessive leaching of nitrates and minerals. Figure 58 shows a modern commercial fertilizer factory at Mason City, Iowa.

What Commercial Fertilizers Contain. Commercial fertilizers may consist of compounds which supply one plant nutrient only, or they may consist of a mixture of compounds which supply two or more nutrients. Fertilizers which supply three or more nutrients are frequently called complete or mixed fertilizers. In general, mixed fertilizers contain compounds which supply large quantities of nitrogen, phosphorus, and potassium, and compounds which supply small quantities of manganese, magnesium, boron, zinc, and copper, depending on whether any or all of these elements are deficient in any particular region of the country. In the United States, nitrogen, phosphorus, and potassium are deficient in most soils, and magnesium, manganese, copper, zinc, and boron are deficient in soils in certain areas. For example, magnesium is deficient in certain soils of the Atlantic Coastal Plain; manganese is deficient in certain soils in Rhode Island, Florida, and Virginia; boron is required on many soils east of the Mississippi River; zinc is necessary for certain crops in Florida and California; and copper is required for crops growing on muck soils in New York, Florida, Michigan, and Indiana. The so-called minor nutrients are applied either separately or in mixed fertilizers.

Commercial Fertilizer Terminology. The terms analysis, formula, and ratio are used in connection with the preparation, purchase, and application of mixed fertilizers. Each term has a distinct meaning.

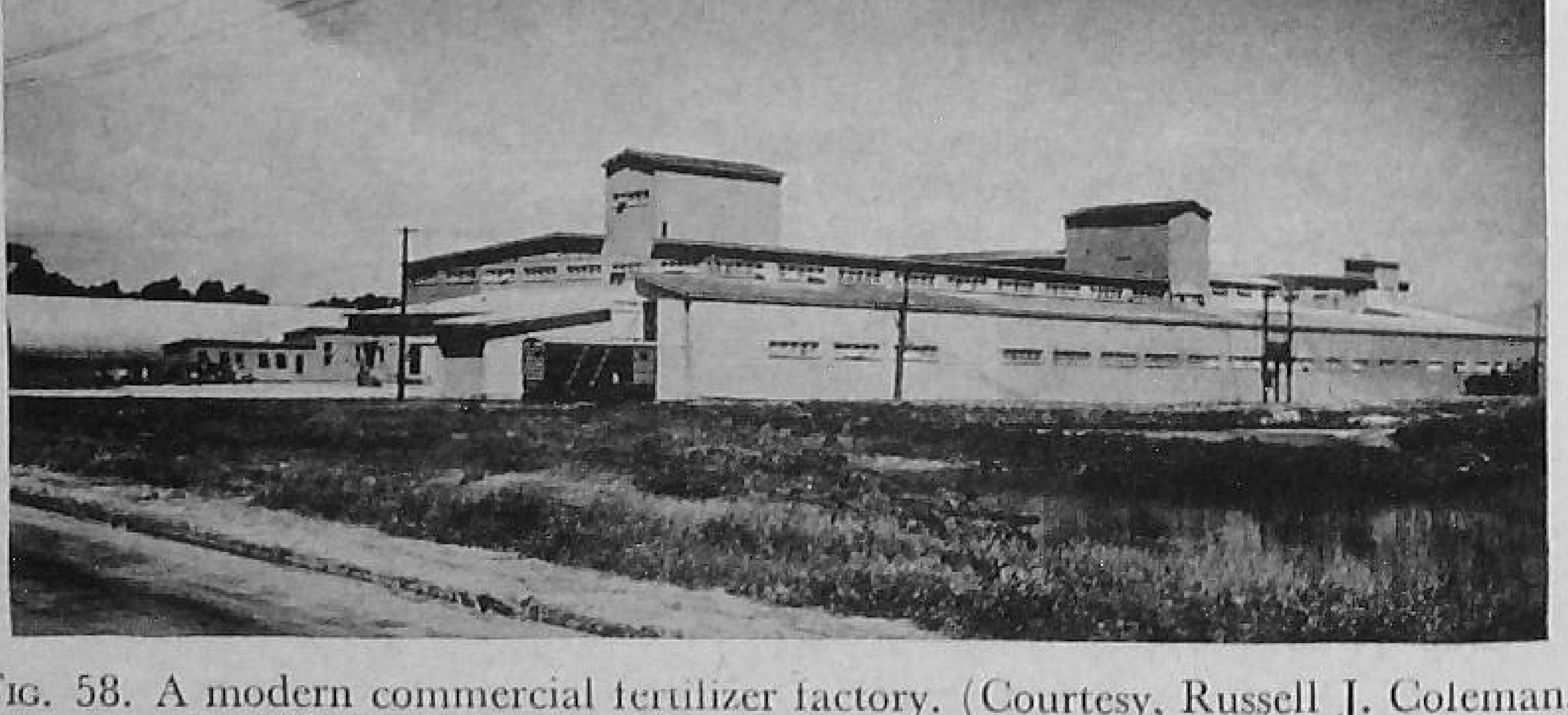


Fig. 58. A modern commercial fertilizer factory. (Courtesy, Russell J. Coleman, The National Fertilizer Association.)

Fertilizer Analysis. The fertilizer analysis is a statement of the percentage of nitrogen, phosphoric acid, and potash in the mixture. Examples are 7–7–5, 5–10–5, and 15–30–15. The first figure denotes the percentage of total nitrogen (N), the second the percentage of available phosphoric acid (P_2O_5), and the third the percentage of water-soluble potash (K_2O). The analysis is usually printed on the fertilizer bag or on a tag.

Fertilizer Formula. The fertilizer formula is a statement of the kind of materials and the quantity of each used to make a ton of mixed fertilizer. Is the nitrogen supplied in the form of sodium nitrate, or in the form of ammonium sulfate, or is it supplied as a mixture of sodium nitrate, ammonium sulfate, cottonseed meal, or some other nitrogen carrier? Is the phosphoric acid derived from 16, 20, or 40 per cent superphosphate? Is the potassium derived from potassium chloride, or from potassium sulfate, or does it consist of a mixture of the two? Growers find a knowledge of the source of the materials indispensable, since two important questions can thus be assured: (1) Does the mixture make the soil more or less acid? and (2) what is the relative availability of the nitrogen in the mixture? For example, sodium nitrate, cal-nitro, superphosphate, bone meal, and basic slag make soils less acid, and ammonium sulfate, leuna saltpeter, and acidulated fish scrap make soils more acid. Thus, the judicious use of commercial fertilizers controls to some extent the degree of acidity of the soil.

Fertilizer Ratio. The fertilizer ratio indicates the proportion of the three major ingredients in mixed fertilizers. A 4–8–4 is an example of a 1–2–1 ratio; a 4–12–4 is an example of a 1–3–1 ratio; and a 4–16–4 is an example of a 1–4–1 ratio. Common ratios used in the United States are: 1–1–1, 1–1½–1, 1–1½–2, 1–2–1, 1–3–1, 1–4–1, 1–2–3, 1–2–4, and 1–4–6. In general, recommendations are made in terms of the analysis or the ratio. An advantage in making recommendations in terms of the ratio is that different analyses of the same ratio may be used to supply the same quantity of nutrients. For example, 4–8–4, 5–10–5, and 15–30–15 have the same ratio. To supply 80 pounds of nitrogen, 160 pounds of phosphoric acid, and 80 pounds of potash, 2000 pounds of 4–8–4, 1600 pounds of 5–10–5, or 533 pounds of 15–30–15 will be required. Thus, for any particular ratio the grower can select moderately high or very high analyses.

Availability of Nitrogen Carriers. Based on their availability, nitrogenous fertilizers are classified as follows: (1) Materials which are available immediately after they are applied, (2) materials which are available a short time after they are applied, and (3) materials which become avail-

able gradually. Sodium nitrate, calcium nitrate, potassium nitrate, and ammonium sulfate are available immediately; urea and calcium cyanamide become available in a short time; and tankage, fish scrap, and cottonseed meal become available gradually. The rate of decomposition of these gradually available materials depends largely on the activity of soil organisms.

Nitrogenous carriers of various degrees of availability have their place in the growing of economic crops. In general, readily available forms are applied when the immediate absorption of large quantities of nitrate-nitrogen is necessary and slowly available forms are applied when a continuous supply of relatively small quantities of nitrate-nitrogen is necessary. For example, fruit growers apply readily available nitrogen just before the trees blossom. At this time the trees begin to develop their twigs; hence, abundant quantities of available nitrogen must be present to make the cells which constitute these twigs. Without an abundant supply at many growing points, many young fruits and vegetative buds would fail to develop. On the other hand, vegetable and flower growers apply nitrogen in the readily available form and in the slowly available form. The readily available forms are usually applied to seedling flower and vegetable crops when the weather is cold and wet, and when the plants are producing large quantities of flowers and fruit. At this time, the natural supply of available nitrogen may be below the requirements for satisfactory growth of the crop.

Concentration of Commercial Fertilizers. Commercial fertilizers vary in concentration. A 3–8–3 is an example of a low analysis, and 5–10–5 or 15–30–15 are examples of a high analysis. In many states, mixtures containing less than 16 or 20 units of nutrients are termed low analysis fertilizers and are not recommended. In general, properly formulated high analyses mixtures cost less per pound of plant nutrients than low analyses mixtures.

SELECTION OF A SUITABLE FERTILIZER

The selection of a suitable fertilizer for crops depends largely on: (1) The nutrient level of the soil with respect to the contents of the fertilizer, (2) the type of growth desired, and (3) the season.

Nutrient Level of the Soil. Both in general and for the same crop, soils in various parts of the country have different fertilizer requirements. For example, the sandy loams of the Atlantic Coastal Plain given over to potato production require 1–1–1 or 1–1½–1 mixtures: 5–8–7 mixtures are

used in Aroostook County, Maine, and 6–6–5 and 5–7–5 mixtures are used in the Tidewater district of Virginia and the truck crop district near Charleston, South Carolina. On the other hand, the loam soils of the Midwest given over to potato production usually require 1–3–1 or 1–4–1 ratios: 4–12–4, 4–16–8, or 4–16–4 mixtures are used in New York, Michigan, Pennsylvania, and Ohio, and 4–8–4 mixtures are used in southern Mississippi and Louisiana. Other examples can be cited.

As stated previously, potassium is the element most needed in muck and peat soils. The degree of decomposition of the peat or muck, the years under cultivation, the drainage, and the acidity are the principal factors in deciding the relative amount of potassium required. Examples of mixtures used are: 0–8–24, 0–10–20, 2–8–16, 3–9–18, 3–12–12, and 4–12–50. Note the low proportion of nitrogen and the high proportion of potash.

Type of Growth Desired. The proportion of nitrogen, phosphorus, and potassium in the mixture depends also on the type of growth desired. The student will recall that if a plant has an abundant supply of carbohydrates in its tissues or is making large quantities of carbohydrates, the supply of available nitrogen in the soil, with other environmental factors favorable for growth, determines the rate of stem and leaf formation. Thus, with other factors favorable, abundant supplies of available nitrogen make for abundant vegetative growth, and moderate supplies make for moderate vegetative growth. For these reasons, when vigorous vegetative growth is necessary, as, for example, the growth of woody plants in the spring and the growth of vegetable and flower crops in the seedling stage, abundant supplies of available nitrogen are necessary. Conversely, when moderate vegetative growth is necessary, only moderate supplies of nitrogen are necessary.

The Season. For the same crop grown on the same soil in the same locality, the proportion of nitrogen to phosphorus and potassium in many cases depends on the season. Principal factors concerned are the amount of available nitrogen and the amount of available light. The amount of available nitrogen in the soil pertains to the growing of crops out of doors. For example, tests at the Louisiana Experiment Station have shown that snap beans growing on Lintonia silt loam require a 1–2–1 ratio in the spring and a 0–1–1 ratio in the fall. Other examples could be cited. Evidently, the relative activity of soil microörganisms and the amount of organic matter are responsible for the different amounts of nitrogen that should be applied.

The amount of available light pertains largely to the growing of crops

in the greenhouse. As stated before, the amount of light and nitrogen available frequently determines the type of growth a plant is making. For example, fall crops in the greenhouse are usually started under better light conditions than spring crops. The longer photoperiod and higher light intensity of the early fall makes for a high carbohydrate supply. Thus, with moderate quantities of available nitrogen not all of the carbohydrates are used for vegetative growth; some are allowed to accumulate for the initiation of the flower buds and the development of the flowers, fruit, and seed. Were the same quantities supplied in early spring, practically all of the carbohydrates would be utilized in vegetative growth and none would be left for reproductive growth.

RATE OF APPLICATION

The rate of application refers to the amount of commercial fertilizer applied per unit area of land. For crops grown in orchards, groves, vineyards, and fields, the rate is made on the basis of one acre, and for crops grown in greenhouses and gardens, the rate is usually made on the basis of 100 square feet. In general, the rate of application depends on: (1) The analysis or concentration of the mixture and (2) the cash value of the crop.

Analysis or Concentration. As stated previously, high analysis mixtures contain more nutrients per pound than low analysis mixtures. Thus, the mixture must be considered from the standpoint of pounds of nitrogen, phosphoric acid, and potash which it contains. For example, if a grower wishes to use 80 pounds of nitrogen, 160 pounds of phosphoric acid, and 160 pounds of potash per acre, he may use 1600 pounds of 5–10–10 or 1000 pounds of 8–16–16.

Cash Value of the Crop. When the yield of a crop is worth from 40 to 50 dollars per acre, the outlay for commercial fertilizers can only be a relatively few dollars per acre. However, when the yield of a crop is worth from 100 to 200 dollars per acre, the outlay for commercial fertilizers can be relatively more. Thus, with other factors equal, the amount of fertilizer used depends to some extent on the actual value of the product. For example, vegetable crops grown for the cannery generally have a lower cash value than the same crops grown for the fresh market. Applications for crops grown for the cannery generally vary from 400 to 1000 pounds per acre, while applications for the same crop grown for the fresh market vary from 800 to 2000 pounds per acre.

TIME AND METHOD OF APPLICATION

The time of application of commercial fertilizer depends largely on the kind of plant. With woody plants commercial fertilizers are usually applied when they are starting growth in the spring. At this time these plants are developing their twigs rather rapidly and hence they require large quantities of nutrients. With vegetable or flower crops commercial fertilizers are applied a few days before or at the same time the seeds or plants are planted and supplementary applications are made later. If the fertilizer is applied by means of a distributor attached to a seed drill, it is usually applied at the time the seed is planted.

Commercial fertilizers are applied to soils in various ways. Principal methods are: (1) Broadcasting, (2) the row method, and (3) side placement.

Broadcasting. Broadcasting consists of applying the fertilizer evenly over the entire surface of the soil. It is usually done after the land is plowed and before it is harrowed. Harrowing mixes the fertilizer with the upper 3 or 4 inches. This method is used to apply nutrients to crops which are grown close together, such as grain and cover crops, and to crops which are grown in narrow rows, such as spinach, carrots, lettuce, onions, lilies, and gladiolus.

The Row Method. The row method consists of applying the nutrients at the bottom of the furrow a week or 10 days before the seed is planted. Usually the fertilizers are mixed with the soil and the land is ridged. This places the fertilizer directly below the plants. At present this method is used to supply nutrients to many vegetable and flower crops grown in the South. A disadvantage of this method is that the roots of plants are likely to become injured by the fertilizer salts. This is particularly true on light soils.

The Side Placement Method. The placement method consists of applying the fertilizer in a continuous or discontinuous band on one or both sides and on the same level or just below the level of the seed or plants. Investigations at the Virginia Truck Experiment Station have shown that placing the fertilizer on the side of the seed of many vegetable crops produces greater yields than placing the fertilizer below the seed. There are definite reasons for the greater yields. The fertilizer is placed sufficiently close to the seed so that the roots of the young seedlings reach the nutrients in a relatively short time. In this way losses due to leaching are prevented and relatively small quantities of the available forms of phosphorus are

FIG. 59. The side-dressing of tomatoes growing for the cannery in New Jersey. (Courtesy, Jackson B. Hester, Campbell Soup Company.)

changed to the relatively unavailable forms. Where small quantities of fertilizer are used, the side placement method is particularly advantageous. Figure 59 shows the side placement of commercial fertilizers to tomatoes growing for the cannery in New Jersey.

CHEMICAL QUICK TESTS

Chemical quick tests have been developed to determine the nutritional requirements of economic plants. They are of two types: (1) Soil and (2) plant.

Soil Tests. These tests consist of a quick chemical analysis of nutrients in a small sample of soil solution. The soil sample is extracted with a weak acid or with the salt of a weak acid. Aliquots of the extracted solution are treated with chemical reagents. Diphenylamine is used to test for nitrates; ammonium molybdate is used for phosphorus; and sodium cobaltinitrite is used for potassium. The object of the soil tests is to determine the degree of fertility of the soil. If the soil is well supplied with nutrients it gives a good test; if it is moderately supplied it gives a fair test; and if it is poorly supplied it gives a poor test. Investigations at the Virginia Truck Experi-

ment Station have shown that the soil tests for phosphorus and potassium agree fairly well with responses and yield of many vegetable crops grown in the area.

Plant Tissue Tests. These tests consist of a quick chemical analysis of a small portion of a few plants. In general, a portion of the stems or petioles is used. The sample is extracted with a weak acid and the nutrients in the extract are determined with the same reagents and in practically the same manner as those in soil extracts. The plant tissue tests show the nutrients which are lacking or unavailable in soil and those which are in quantities sufficient for abundant yields. Experiments show that the soil and plant tissue tests have a useful function provided they are done by persons who have a working knowledge of the characteristics of the soil and of the nutritional needs of the crop under consideration.

Questions

1. What are commercial fertilizers?
2. In a strict sense commercial fertilizers are not plant foods. Explain.
3. The foods of plants and the foods of animals are the same substances. Explain.
4. The greatest areas of consumption of commercial fertilizers are located in southeastern United States. Give two reasons.
5. What is a complete or mixed commercial fertilizer?
6. Differentiate between fertilizer analysis, fertilizer formula, and fertilizer ratio.
7. Give two reasons why growers should have a working knowledge of the fertilizer formula.
8. One thousand pounds of a 5–10–5 equals 500 pounds of a 10–20–10. Explain.
9. Fertilizer recommendations may be made on the basis of pounds of N, P_2O_5, and K_2O required per acre rather than on the basis of pounds of any particular analysis. Explain.
10. Given two complete mixtures: mixture A containing 20 units and mixture B containing 16 units. On the basis of current prices of each mixture, determine the cost of each unit in A and B.
11. In fertilizer practice the needs of the soil, the needs of the crop, and the season of the year should be considered. Explain.
12. With other factors equal, the proportion of available nitrogen in the fertilizer should be higher for vigorous vegetative growth than for moderately vigorous growth. Explain.
13. Tomatoes started in January and grown in the greenhouse frequently set very few fruits of the first cluster while the same variety started in August generally sets most of the fruit. Explain.

14. Applications of commercial fertilizer 2 to 3 inches above the seed piece of potatoes generally produce injurious effects. Applications 3 to 4 inches away and on the side from the seed piece generally produce beneficial effects. Explain.
15. In general, small quantities of commercial fertilizer, 100 to 300 pounds per acre, should be applied as side dressings or in hills, while applications varying from 1500 to 2000 pounds per acre should be applied broadcast. Explain.
16. What are chemical quick tests? What are their uses?

11

Plant Growing Structures

Assignment 16

Many kinds of horticultural plants are grown in various plant growing structures. In general, these structures provide a more favorable environment for growth and development than is available in the immediate outdoors. Thus, the growing of crops in structures has the following advantages: (1) Products can be placed on the market earlier or later than those produced outdoors, and (2) plants can be protected from adverse environmental conditions.

The production of crops in plant growing structures is called plant forcing. In many communities forcing is a very important industry. Two types of forcing industries exist: flower forcing and vegetable crop forcing. Of the two industries, commercial flower forcing is the more extensive and valuable. In 1940 approximately 9000 establishments were given over to the production of both flower and vegetable crops, and 2000 establishments were used for the growing of vegetable crops only. Most of these establishments are located in the Midwest and Northeast region of the country.

Nature of Crop Forcing. The growing of plants in forcing establishments is a most intensive type of agriculture. Plants are grown close together and crops follow each other in quick succession. The initial capital required and costs of production are higher than other forms of crop production. In addition, the four principal environmental factors influencing growth and development, water, temperature, light, and

nutrients, are under either entire or partial control. The water and nutrient supply are under the control of the grower at all times; the temperature is under his control most of the time and the light some of the time. In other words, the grower of forcing crops can regulate the plant's environment to a greater extent than the grower of outdoor crops. For this reason the grower of forcing crops usually produces large yields of high quality products.

TYPES OF PLANT GROWING STRUCTURES

Structures used to grow plants are: (1) Greenhouses, (2) hotbeds, and (3) cold frames. In general, these structures are located on well-drained land, preferably with a south or southeast exposure, since protection from northerly and northwesterly winds is usually desirable.

Greenhouses

The various types of greenhouses are: (1) Lean-to, (2) uneven span, (3) even span, (4) ridge and furrow, and (5) curvilinear. *Lean-to* houses consist of a single span. This type is built usually on the south or east side of a wall or house for the forcing of crops, or on the north side of a wall or house for the rooting of cuttings. The lean-to is relatively simple in construction and inexpensive. *Uneven span* houses have two spans, each of unequal width and pitch. Usually one side covers two-thirds or three-fourths the width of the house, and the other side covers one-third or one-quarter. This type of house is generally used on sloping ground and runs from east to west. *Even span* houses have the two sides equal in width and pitch, and may run from north to south and from east to west. *Ridge and furrow* houses are two or more even span houses built together. The inner gutters may or may not have side walls. This type of construction is used primarily where one particular crop occupies several adjacent houses. It does not permit extensive side ventilation. *Curvilinear* houses have curved roofs which require curved sash bars and curved glass. They make the building very expensive. Figure 60 shows in outline form the several types of greenhouses.

Types of Construction. Greenhouses vary in width and length. In general, wide houses (30 to 60 feet in width) are more easily heated and ventilated and cost less per square foot than narrow houses (10 to 30 feet in width). The length varies from 50 to 300 feet. Three types of construction are used: (1) All-wood frame, (2) semi-iron, and (3) iron. The *all-wood* frame is made entirely of wood and is more shady than the other

types of construction. The *semi-iron* frame is part wood and part iron; usually the purlins and posts are made of iron and the gutters and eaves of wood. The *iron* frame is used for very large houses.

The parts of a greenhouse are: (1) The foundation, (2) the braces and purlins, (3) the gutters and eaves, (4) the sash bars, and (5) the glass. The *foundation* supports the entire house and consists of posts which are placed on the inside and walls which are on the outside. The posts are usually imbedded in concrete and the walls are usually made of it, since

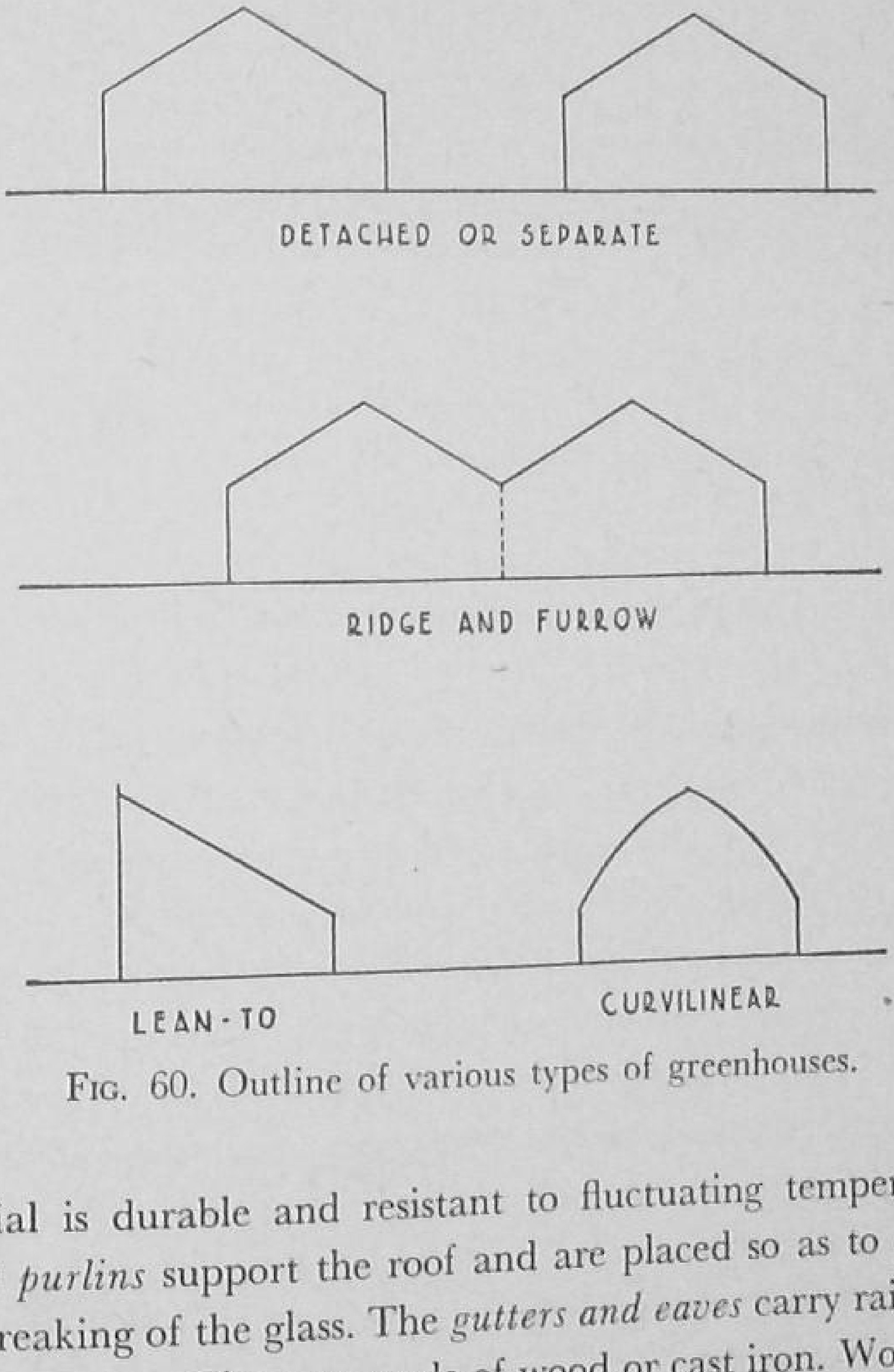


FIG. 60. Outline of various types of greenhouses.

this material is durable and resistant to fluctuating temperatures. The *braces and purlins* support the roof and are placed so as to prevent sagging and breaking of the glass. The *gutters and eaves* carry rain water into the drainage system. They are made of wood or cast iron. Wooden gutters are less durable and usually less satisfactory than iron gutters. The *sash bars* support the glass. They are made of heart cypress or redwood. The *glass* admits the light. Two grades are available, AA and A. Of these grades, AA is preferable because of its strength and resistance to stresses and strains. The 16 x 24 inch size is the most widely used. Figure 61 is an air-view of the range of the J. W. Davis Greenhouse Company, Terre

Fig. 61. The greenhouse range of the J. W. Davis Company, Terre Haute, Indiana. This range, the largest vegetable forcing establishment in the country, covers 25 acres and is given over to the production of vegetable crops, particularly greenhouse tomatoes and cucumbers. (Courtesy, W. Keith Owen, J. W. Davis Company.)

Haute, Indiana. This range covers 25 acres. Principal crops are tomatoes and cucumbers.

Methods of Heating. Greenhouses are heated either by hot water or by steam. Hot water systems are: (1) Gravity open tank, (2) gravity pressure tank, and (3) accelerated circulation. These systems depend on the ability of hot water to displace cold water. In this way constant circulation of hot water through the heating system is attained. The accelerated system differs from the gravity system in that some force is used to hasten the circulation of the water. For short greenhouses the gravity open tank and the gravity pressure tank systems are satisfactory. For relatively long houses the accelerated circulation system is more desirable.

Steam heating systems are: (1) The low pressure and (2) the high pressure. In the low pressure system, from 5 to 15 pounds of steam per square inch is maintained both in the boiler and in the heating coils. In the high pressure system, about 60 to 80 pounds of steam is maintained in the boiler and 5 to 10 pounds in the coils. In general, the low pressure system is more satisfactory for small-sized ranges, and the high pressure system is more satisfactory for large-sized ranges.

Hotbeds

Hotbeds consist of three parts: the frame, the cover, and the heating material or system. In general, the frame is made of wood, concrete, or brick and is usually 24 to 36 inches high on the north or west side, and 12 to 24 inches high on the south or east side. Covers used are glass sash, glass substitutes, canvas, or cloth. Glass sash are wooden frames, usually 3 x 6 feet, in which panes of glass are set; glass substitutes are wooden frames in which light, translucent or transparent waterproof material is set; and cloth covers consist of muslin, canvas, or burlap. Hotbeds are heated by various materials and systems and are classified accordingly.

Manure. The manure heated bed is the oldest type and the least efficient. Fresh horse manure is used and may be placed on or below the surface of the land. In general, the depth of manure varies with the climate and the temperature requirements of the crop. For example, in the South in average weather from 8 to 18 inches will suffice, while in the North greater depths, about 18 to 36 inches, are required. The function of the manure is to produce heat. The process concerned is fermentation—a type of respiration. Note the equation.

$$\underset{\text{(organic matter)}}{\text{Manure}} + H_2O + O_2 \xrightarrow{\text{(soil organisms)}} CO_2 \text{ and other gases} + H_2O + \text{heat} + \text{other forms of energy}$$

As in the decomposition of organic matter, warm-moist manure decomposes more rapidly than cool-moist manure, warm-wet manure, or warm-dry manure. With warm-moist manure the principal environmental factors, temperature, oxygen, and water, are most favorable for rapid decomposition and heat production. When the manure is cold, wet, or dry, temperature, oxygen, and water respectively become the limiting factors. The necessity for rapid decomposition and rapid liberation of heat explains why growers turn the manure pile inside out at frequent intervals; why they prefer manure from grain fed animals; why they apply hot water when the weather is cold; and why they see that the manure does not become saturated with water. Figure 62 shows a cross-section of a manure heated hotbed.

Since manure is scarce, investigators have compared the heat producing capacity of other kinds of organic matter. For example, in 1932 tests at the Kentucky Experiment Station showed that shredded corn stalks, if packed at a depth of 12 to 15 inches in the hotbed pit and thoroughly

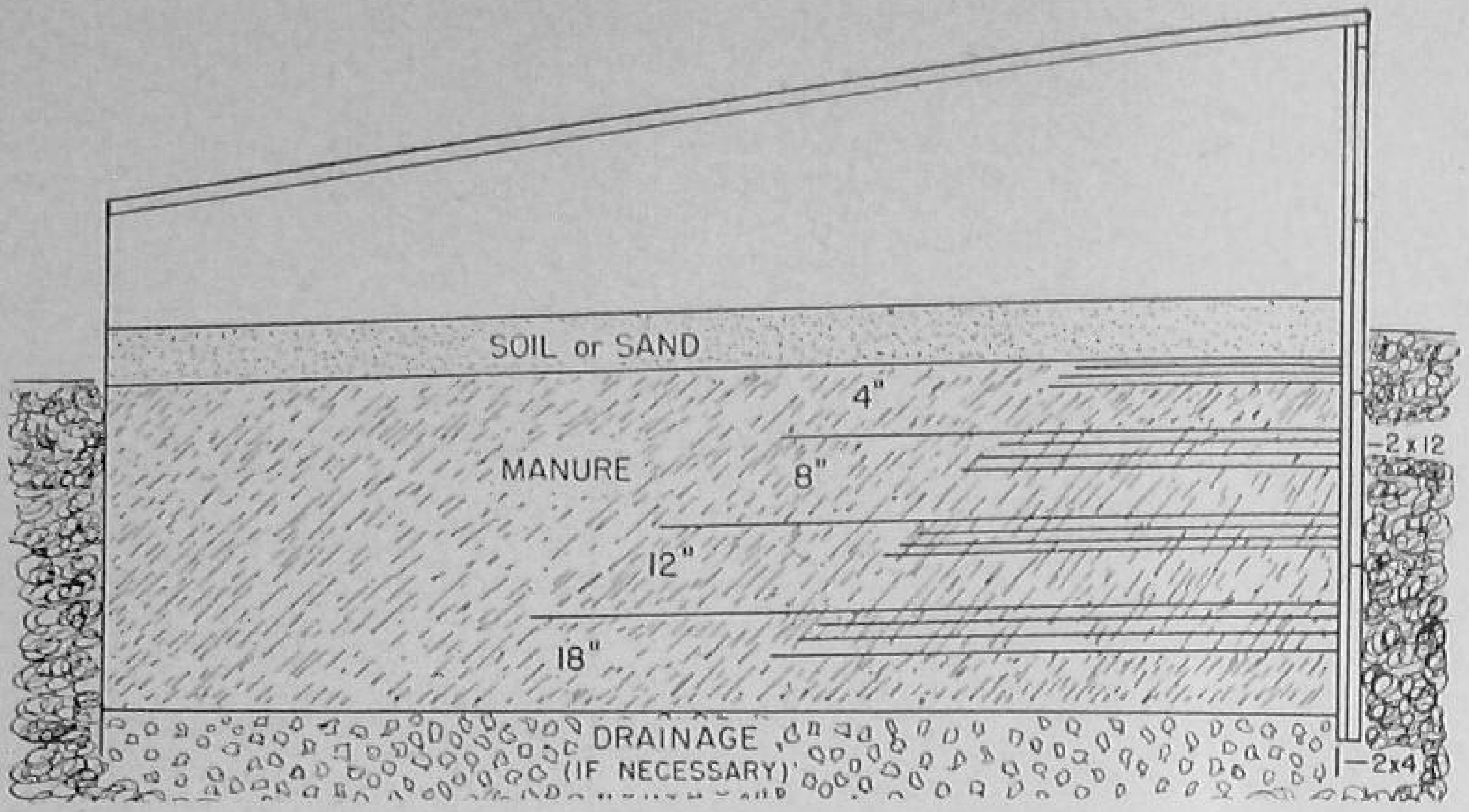


FIG. 62. Cross-section of manure heated hotbed. Note varying depths of manure depending on the climate and temperature requirements of the crop.

moistened, decomposed at rates sufficient to produce temperatures of 100° F. in 2 or 3 days and from 80° to 120° F. for about 1 month. The addition of cottonseed meal to the stalks induced higher temperatures and prolonged the period of heating. However, the investigators experienced difficulty in soaking the stalks.

Hot Air. The hot air heated bed contains sets of flues which carry the heat and products of combustion from the furnace, usually situated at one end of the bed, to the chimney, usually situated at the other end. The reaction concerned is combustion which, like respiration, liberates heat and other forms of energy. Note the equation.

$$\text{Gas or coal or wood} + \text{oxygen} \longrightarrow CO_2 \text{ and other gases} + H_2O + \text{heat} + \text{other forms of energy}$$

Flue heated beds are usually used where growers have plentiful supplies of cheap wood. In general, the direction of the prevailing wind and the length and size of the flue are important considerations. For example, in the production of sweetpotato plants in the South, beds 9 x 12 feet wide and 50 x 60 feet long, underlined with two to four rows of 6- or 8-inch tile, have produced satisfactory results.

Hot Water. The hot water heated bed has pipes under the bed or along the sides of the frame. The size of the pipes, position of the boiler, and slope of the floor are primary considerations in this type of bed. The heaters are usually thermostatically controlled. Thus, they maintain uniform temperatures with little waste of fuel and are economical and ef-

ficient. This type of hotbed is very popular among market gardeners in New Jersey.

Electricity. The electric bed is heated by lead covered resistance coils placed on or under the soil or along the inside walls of the frame or by lamps placed over the bed. This system is automatic, always available, more or less permanent, and reliable. At present, the cost of electricity for the growing of plants is a prime consideration. Thus, many experiments have been made to determine production costs. For example, in 1938 the cost of the electricity was about 2.8 cents per week per sash at the Washington and Pennsylvania Stations and about 1.5 cents per week per sash at the Maryland Station. At the Minnesota Station the combined use of the heating cable and lamps produced better plants than the use of the heating cable alone. This is to be expected since light is usually the limiting factor in growing plants under glass in the early spring in northern climates.

Cold Frames

Cold frames are used to protect plants from frosts, hard rains, and heavy winds. In regions characterized by mild winters herbaceous crops are started in these structures. Later, as the weather becomes warm, the covers are removed. Two types exist: (1) Temporary and (2) permanent. The temporary type is usually made of wood (cedar, locust, or chestnut). Permanent types are made of concrete, concrete blocks, or brick.

PLANT PROTECTION IN THE FIELD

Many kinds of economic crops grown in the field are given protection. Light frosts and heavy winds are the principal environmental factors concerned. Growers have developed many ways by which plants may be protected from these adverse environmental conditions. The various types of protectors are classified as: (1) Those which protect individual plants and (2) those which protect plants in groups.

Individual Plant Protectors. Individual protectors are used to serve two major purposes: (1) To protect plants from frost and cold winds and (2) to promote growth. Examples are: (1) Small, box-like structures with an adjustable pane of glass on the top, sometimes called forcing boxes and (2) chemically treated paper made in the form of a cone. The most common type of cone protector is known as Hot Kap (see Figure 63). The profitable use of individual plant protectors seems to depend on weather conditions. From 1925 to 1931, the influence of ten different types of plant

FIG. 63. Plant protectors over tomatoes in South Carolina.

protectors on the growth of seedling tomatoes and peppers was investigated at the Michigan Experiment Station. Under the conditions of the experiment, the protectors were found to be of decided value in 1925, of doubtful value in 1926 and 1928, and of no value in 1927, 1930, and 1931.* The investigators found weather conditions so variable that it was impossible to assert that the protectors were beneficial in all years. From 1932 to 1935, the effect of five different types of plant protectors on the growth of seedling cantaloupes was investigated in southern Arkansas. Under the conditions of the experiment, all plant protectors hastened germination and seedling emergence from 1 to 4 days and gave a more complete stand. Some types actually increased earliness of yield and total yield. Thus, positive results may be obtained in one part of the country and doubtful results in another. Other types of plant protectors are shingles, newspapers, and brush. Brush is used extensively by growers of cantaloupes in the Imperial Valley of southern California.

Group Plant Protectors. In many districts plants are protected in groups. Such protection is given by: (1) Hedges, (2) buildings, (3) V-shaped troughs of 12-inch boards, (4) strips of crop plants, and (5) southerly or southeasterly slopes. The kind of protection used depends largely on the kind of enterprise. For example, *hedge protection* is used by the growers of slicing cucumbers in the vicinity of Norfolk, Virginia. Cedar hedges on the west, north, and east sides of small tracts (1 to 5

*No out-door tests were conducted in 1929.

acres) give the necessary protection from cold winds. *Building protection* is used by market gardeners and florists, particularly in the North, where protection from cold north and northeasterly winds is essential. *Protection by V-shaped troughs* is used by growers of cucumbers in Florida. These troughs are placed on the north side of the rows of cucumbers. In this position protection is given from wind and the reflection of sun rays from these troughs helps germination and growth of the young plants. If frosts are likely to occur, the troughs are placed over the plants. *Protection by strip cropping* is used by growers of onions in New York and Michigan. The strips of barley or oats protect the young plants from the injurious action of the rather heavy winds. *Southerly or southeasterly slopes* are used by market gardeners, since these slopes warm up earlier in the spring than northerly or northwesterly slopes.

PLANT CONTAINERS

Plant containers have two rather distinct functions: (1) The growing of plants to full maturity and (2) the growing of plants for transplanting to the field, garden, greenhouse bench, or bed. They are classified as follows: (1) Plant containers used to raise plants in groups and (2) plant containers used to raise plants individually.

Group Containers. The principal type of group container is called a flat. The flat is essentially a shallow tray. Its width varies from 6 to 24 inches, its length from 18 to 36 inches, and its depth from 2 to 6 inches. Commercial growers usually use flats of standard dimensions—12 x 24 x 3 inches. Their use facilitates standardization of other crop-growing operations, and more efficiently utilizes greenhouse, hotbed, and cold frame space. In general, durable, non-warpable wood is used. Recently, metal flats with holes in the bottom for drainage have become available. Note the two general methods of planting seed in the flats in Figure 64.

Individual Containers. Individual plant containers are: (1) Pots and (2) bands. Pots are round in outline and may or may not have a hole in the bottom for drainage. Bands are square in outline and are open at the bottom. Pots are either porous or non-porous. Porous pots are made of clay or peat fiber and non-porous pots are made of metal, concrete, rubber, and plastics. Bands are made of wood or paper.

Principal factors concerned in the growing of plants in pots or bands are: (1) The water supply and (2) the nitrogen supply. The water supply pertains particularly to porous and non-porous pots. Investigations at the Massachusetts Experiment Station have shown that, under the same con-

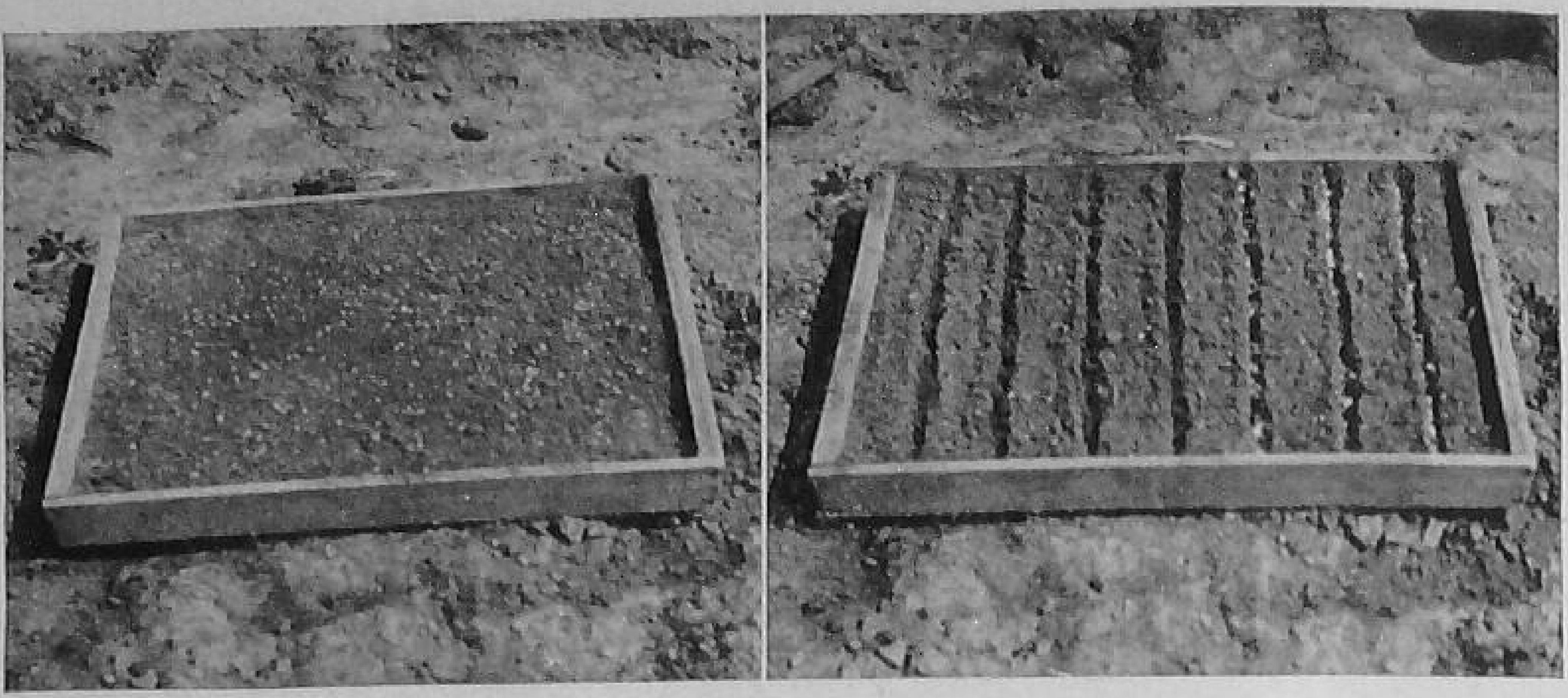


FIG. 64. A standard flat. (*Left*) Seed broadcast. (*Right*) Seed planted in rows. (Courtesy, K. H. Buckley, Mississippi Agricultural Extension Service.)

ditions, plants in non-porous pots required less moisture than those in porous pots. Consequently, failures through the use of non-porous pots are likely to be due largely to overwatering, while failures through the use of porous pots are likely to be due to excessive drying-out or underwatering. If moist soil is constantly maintained in either case, either type of pot should be equally satisfactory.

The nitrogen supply pertains particularly to new clay pots and to paper and peat fiber pots. Tests have shown that new clay pots absorb nitrates. Thus, unless adequate available nitrogen is supplied in the irrigation water, rapidly growing plants are likely to be deficient in nitrogen. Tests also have shown that microörganisms decompose paper pots. Here again, unless adequate available nitrogen is supplied, rapidly growing plants are likely to become deficient in nitrogen. In general, applications of available nitrogen at the rate of 1 ounce of sodium nitrate or ammonium sulfate to 1 gallon of water at intervals of 1 week or 10 days will suffice to supply the nitrogen requirements of the plants and the decomposing bacteria.

USES OF POTS AND BANDS. *Pots* are used to raise plants for transplanting or to full maturity, and bands are used to raise transplants only. Of the many types of pots on the market, clay pots are the oldest and most popular. Many sizes are available, varying from 2, 2¼, 3¼, 4, 5, 6, and 7 inches in diameter. Other types of pots are innovations. The metal type, for example, is quite ornamental and somewhat adapted to the growing of plants in the home or conservatory. *Bands* are made of either wood veneer or paper. The most popular sizes are 2 x 2 x 3, and 4 x 4 x 5 inches. Figure 65 shows various types of pots.

Ornamental Plants and Pot Size. The amount of growth a plant will

FIG. 65. Examples of individual containers. (*Front row*) Standard clay pots of various sizes. (*Second row*) Notched clay pot, veneer band, paper pot for growing, paper pot for shipping, plastic pot, and rose pot. (*Third row*) Orchid pot, pan, standard pot showing single hole for drainage. (*Fourth row*) Large clay pot, cypress tub. (Courtesy, E. W. McElwee, Mississippi State College.)

make and the time it will flower depends largely on the immediate and potential available nitrogen supply. This in turn depends on the volume of soil in which the plant is growing, which in turn depends on the size of the pot. In general, plants growing in small pots produce less vegetative growth and flower earlier than plants growing in large pots. Plants growing in small-sized pots will naturally deplete the nitrogen supply earlier than plants growing in large-sized. The earlier depletion will permit earlier accumulation of carbohydrates and flower-forming substances, which in turn are associated with flower bud formation, flowering, and fruiting.

Growing Seedling Vegetable Plants. Certain vegetable crops, particularly tomatoes, cabbage, and onions, are raised during the seedling stage in relatively cool weather in southern United States and shipped as transplants to market gardeners and canners in northern United States. Because of the necessity for strict control of diseases, the raising of these crops is a highly specialized industry. The seedling plants are grown in open fields of 1 to 100 acres or more. Relatively infertile, well-drained sandy loams and loams are used. In general, the seed is drilled in rows 6 to 12 inches

Fig. 66. A field of tomato transplants in the Tifton-Valdosta district of Georgia. In general, the plants are "lifted" when they are 6 to 10 inches tall and are shipped by express train or plane to growers of tomatoes in the Northeast and Midwest. (Courtesy, Otis Woodard, Georgia Coastal Plain Experiment Station.)

apart. On many plant growing farms the amount of seed used is numbered in tons and the number of plants produced is counted in millions.

Two important plant growing districts are the Rio Grande Valley of Texas and the Tifton-Valdosta of south Georgia. The Rio Grande Valley produces annually some 160 million sweetpotato plants, 100 million tomato plants, 400 million cabbage plants, and 900 million onion plants. The Tifton-Valdosta area comprises about 5 counties and produces approximately 100 million sweetpotato plants, 500 million tomato plants, 400 million cabbage plants, and about 20 million onion plants. Small quantities of pepper, eggplant, and cauliflower seedlings are produced also. Figure 66 shows a field of tomato transplants in the Tifton-Valdosta district.

Questions

1. How does the growing of crops in plant forcing structures differ from the growing of crops outdoors?
2. For the same crop higher yields and higher quality are generally produced in greenhouses than outdoors. Explain.
3. Draw an outline of the cross-section of a lean-to house, an even span house, an uneven span house, and a group of ridge and furrow houses.
4. Give the function of the following parts of a greenhouse: the foundation, the braces and purlins, the gutters and eaves, the sash bars, and the glass.

5. Hot water circulates faster than warm water. Explain.
6. In general, greenhouses produce better plants than hotbeds and cold frames. Explain.
7. Give the three parts of a hotbed.
8. In general, with other factors favorable, the rate of heat production from manure varies directly with temperature. Explain.
9. The manure for hotbeds should be moist but not wet. Give two reasons.
10. Draw a cross-section of a manure heated hotbed, of a flue heated hotbed.
11. What difference is there, if any, between the decomposition of organic matter in soils and the decomposition of manure in hotbeds?
12. Name the advantages and disadvantages of electric heated hotbeds.
13. How would you change an electric heated hotbed into a cold frame?
14. The grower of crops for early market frequently protects his plants. Explain.
15. Cantaloupe growers in the Imperial Valley, California, place brush on the north side of the furrows in early spring. Explain.
16. Your mother wishes information on protecting tomato plants she has just set in the garden. Outline a practical measure.
17. In your opinion how do hedge protection and strip cropping influence the photosynthesis of the protected crop?
18. How does planting on a southeast slope promote earliness?
19. Flats and pots should be set level on beds and benches. Explain.
20. The soil in a porous pot drys out more quickly than that in a non-porous pot. Explain.
21. Your mother wishes information on the type of pot she should use for growing plants in the living room. Give reasons for the type of pot you would recommend.
22. Given two lots of plants growing in paper pots. Plants of lot A have uniformly yellow stems and are making slow growth; plants of lot B have dark green leaves and are making rapid growth. State the nutrient deficiency and prescribe treatment.
23. Given two plants. Plant A is grown in a porous pot; plant B is grown in a non-porous pot. Both plants are grown side by side in a greenhouse and are given the same (moderate) supplies of water. Which plant would flower first? Give your reasons.
24. Given two plants. Plant A is potted in a 4-inch pot; plant B is potted in an 8-inch pot. Which plant would flower first, and make the greater growth, size, and dry weight? Explain fully.
25. Your mother has a vigorously vegetative geranium plant growing in rich soil. She gives the plant abundant water. She wants the plant to produce flowers at the earliest possible moment. What would you advise?
26. Tomato and cabbage plants grown in southern United States for shipment to midwestern United States are raised in relatively infertile, well-drained sands and sandy loams. Explain.

12

Transplanting—Cultivating—Irrigating

Assignment 17

TRANSPLANTING

Transplanting is a most important practice. The many thousands of deciduous fruit trees, evergreen fruit trees, and nut fruit trees, and the many millions of ornamental trees and shrubs in this country and throughout the world have at one time or another been transplanted to the place where they are now growing. Moreover, many millions of vegetable and flower plants are transplanted annually. Thus, the many kinds of deciduous fruit orchards, citrus orchards, and small fruit, vegetable, and flower crop plantations are established; and parks, lanes, highways, and homes are made more beautiful.

There are many kinds of transplanting: potting, repotting or shifting, "pricking off," balling, and setting out. Potting is the removal of seedlings from a seed bed or flat to a pot. Repotting or shifting is the removal of a plant from one pot to another, usually to a larger one. "Pricking off" is the removal of seedlings to flats or beds. Balling is the removal of plants, chiefly evergreens, with a ball of soil supported by burlap or similar material. Setting out is the removal of plants from pots, flats, or beds to the garden or field. All of these kinds of transplanting involve displacement of the root system.

Influence on Plant Behavior. How does transplanting influence growth and development? What are the fundamental processes concerned? The

student should remember that *transplanting always destroys part, if not all, of the region of absorption of the root system.* Thus, the amount of water going into a plant during transplanting operations is reduced or entirely stopped. Since transpiration continues and since the income of water is reduced or entirely stopped, *the immediate or initial effect of transplanting is a reduction in the water supply within the plant.* This reduction in the water supply reduces the rate of cell division and cell elongation. This in turn reduces the rate of carbohydrate utilization and increases the rate of accumulation.

The next effect of transplanting is a decrease in the turgor pressure of the guard cells. As a result the guard cells and stomata decrease in size; the rate of diffusion of carbon dioxide decreases; and photosynthesis decreases. Thus, the transplanting of plants in full leaf is a harmful practice. In other words, transplanting injures plants and the extent of the injury is roughly proportional to the reduction in the water supply.

Of the factors influencing transpiration, the area of the leaf surface is most important. When the leaf area is very small or entirely absent, temperature, relative humidity, light intensity, or wind velocity will have less effect on the outgo than when the leaf area is very large. Thus, if the grower transplants his plants when they are not in full leaf, he will remove them when the outgo is at a minimum. Many growers can do this and many cannot. Frequently, they must transplant their plants when they are in full leaf. For example, deciduous trees can be transplanted without leaves. On the other hand, evergreen and herbaceous plants must always be transplanted with leaves.

Herbaceous Crops

The principal factors concerned in the rate of recovery of herbaceous crops incident to transplanting are: (1) Size and age of plant, (2) kind of plant, and (3) treatment at transplanting.

Size and Age of Plant. Recovery varies indirectly with size and age. In other words, the greater the size or age, the lesser the ability of the plant to recover from the check in growth incident to transplanting. Since size and age are positively associated, these factors may be considered collectively. How do large or old plants recover less rapidly than small or young plants? When large or old plants are removed, a smaller amount of their absorbing roots is retained than when small or young plants are removed. Therefore, the rate of income in proportion to the rate of outgo is materially reduced in the case of the large or old plant. Thus, whenever

it is possible, feasible, and practical, herbaceous plants should be transplanted in the seedling stage. Growers who transplant large numbers of plants, the market gardeners and florists, generally transplant seedling plants when they are small—usually immediately after the first true leaves begin to develop.

Kind of Plant. Some kinds of herbaceous plants recover rather quickly; others recover slowly. This differential rate of recovery can be explained from differences in three distinct types of behavior. These are: (1) Rate of root regeneration, (2) rate of top growth, and (3) age of the roots within which suberization takes place.

Rate of Root Regeneration. A direct relation exists between the rate at which a new root system is formed and the rate of recovery. In other words, with other factors in favorable supply, the faster the new root system is formed, the greater is the rate of recovery. The rate at which a new root system is formed is dependent on a supply of carbohydrates within the tissues. Thus, with other factors equal, plants with large quantities of reserve carbohydrates in their tissues may be expected to recover more rapidly than plants with small quantities.

Rate of Top Growth. Since the amount of water transpired is directly proportional to the leaf surface, it follows that plants with a rapid rate of top growth will recover less quickly than those with a slow rate. Plants differ in this respect. For example, cucumbers have a more rapid rate of growth than cabbage. They also recover less quickly. Thus, plants with a slow rate of top growth recover more rapidly than plants with a fast rate.

Age of Roots in Which Suberization Takes Place. Suberization of the roots is the laying down of suberin in the walls of the endodermis or cortex in the region of the root hair zone. Since suberin is impervious to water, suberization of the endodermis or cortex in the root hair zone will prevent the passage of water from the root hairs to the xylem. Thus, that portion of the root in which suberization has taken place is useless for water absorption. Plants differ in the time that suberin is laid down in the water-absorbing region. For example, in beans, cucumbers, and sweet corn, suberization becomes evident in the three-day-old portion of the root system and in tomatoes and cabbage it first becomes evident in the five- to six-week-old portion. Naturally, crops in which suberization takes place relatively early in the life of the roots recover less rapidly than those in which suberization takes place relatively late.

On the basis of differential rate of recovery, a classification of herbaceous crops into three groups is possible. These groups are presented in

Table 20. In general, plants of group 1 develop new roots rapidly and lay down suberin relatively late in the life of the root system; plants of group 2 develop new roots moderately rapid; and plants of group 3 develop new roots slowly and lay down suberin relatively early in the life of the root system. This explains why plants of groups 2 and 3 require more care in transplanting than those of group 1. In fact, experience has shown that plants of group 3 must be grown in pots or bands if they are to be transplanted.

Table 20

CLASSIFICATION OF CROPS BASED ON RATE OF RECOVERY FROM TRANSPLANTING

Group 1: Crops Recovering Rapidly	*Group 2: Crops Recovering Slowly*	*Group 3: Crops Recovering Very Slowly*
lettuce, tomatoes, cabbage, stocks	peppers, celery, onions	beans, cucumbers, cantaloupes, poinsettia

Treatment at Transplanting. Treatment at transplanting refers to the use of water and starter solutions. Most herbaceous crops are transplanted with water. In fact, growers believe that the application of water at transplanting is essential to rapid recovery and to securing good stands. The water settles the soil around the roots, thus eliminating air pockets, and is available for immediate absorption. Water is applied by hand or by machine.

Starter solutions contain readily available nutrients in a rather high concentration in the transplanting water. The materials generally used are sodium nitrate, ammonium phosphate, monopotassium phosphate, and potassium chloride. Tests by the New York (Geneva), Florida, New Jersey, and other Experiment Stations have shown that starter solutions markedly increase the rate of recovery of seedling plants of many vegetable crops. The solution promotes rapid recovery and early growth by providing the plants with an adequate supply of readily available nutrients and by stimulating the rate of root regeneration.

HARDENING OF HERBACEOUS PLANTS

Any set of environmental conditions or practices which retards the growth of stems, leaves, and roots induces hardening. To slow down growth, growers usually subject their plants, especially tomatoes and cab-

bage, to moderately low temperatures or to a moderately low water supply or both or produce them on relatively poor soil. Investigations at the Missouri Experiment Station have shown that when plants are hardened there is an accumulation of carbohydrates which results in increases in dry weight and rapid maturation of the tissues. Hardening, therefore, promotes the accumulation of carbohydrates and retards their utilization.

With certain plants, this accumulation of carbohydrates permits the making of substances which bind water so that the plant can withstand subfreezing temperatures, intense sunshine, and dry winds. With other plants, the carbohydrates which accumulate do not form substances which bind water readily. In general, crops which thrive best in cool weather, the cool-season crops, possess the ability to bind water while crops which thrive best in warm weather, the warm-season crops, do not possess this ability. This explains why most cool-season crops can be hardened to withstand relatively low temperatures while warm-season crops cannot. For example, a hardened cabbage plant can withstand temperatures as low as 20° F. A hardened tomato plant cannot withstand freezing temperatures. This does not mean, however, that tomatoes should not be hardened. As stated previously, an advantage of hardening is the accumulation of carbohydrates, which in turn are used for the development of a new root system.

Transplanting Machines. Many herbaceous crops—celery, cabbage, tomatoes, peppers, and sweetpotatoes—grown on a commercial scale are transplanted by machines. These machines set plants at definite intervals

Fig. 67. Machine transplanting of tomatoes in New Jersey. (Courtesy, Jackson B. Hester, Campbell Soup Company.)

and depths, and release a definite amount of water or nutrient solution to the roots. In this way plant setting and watering take place simultaneously. Note the machine transplanting scene in Figure 67.

Deciduous Trees and Shrubs

In general, deciduous trees and shrubs are transplanted most advantageously when they are dormant. During this period transpiration is at a minimum, and the root system has opportunity to become established before stem and leaf growth begins.* Moreover, the longer the time available for the development of a new root system, the greater is the chance for survival when the leaves develop and the plant begins to grow. In southern United States, trees are generally planted in the fall, since the soil temperature is sufficiently high for the development of a new root system during the winter and air temperature and light intensity increase rapidly during the spring. On the other hand, in northern United States, the trees are generally planted in the spring, since soil temperature prohibits root growth during the winter and air temperature and light intensity increase slowly during the spring. However, regardless of the region or the climatic condition, if the trees are in full leaf or are very large they should be removed with a ball of earth.

Evergreen Trees and Shrubs

Because leaves are always present on evergreens, they are transplanted with greater difficulty than dormant deciduous trees and shrubs. To replace the loss of water in a relatively short time after transplanting, a large quantity of the absorbing roots and moist soil must be provided. This is done largely by "balling and burlapping" the roots. The plants are dug with a large part of the roots set in a ball of soil which is held together by burlap. In most regions balling and burlapping and subsequent transplanting of evergreen trees and shrubs are usually done in the fall, winter, and early spring. During these seasons the rate of transpiration is lower than in the summer. However, in southern Florida trees and shrubs are planted during the summer. During this season the rainfall is higher than during the winter season. Because of the high rainfall, the light intensity is low, the relative humidity is high, and, as a result, the rate of transpiration is correspondingly low. Figure 68 shows a balled and burlapped tree ready for transplanting. Note the operations involved.

*Roots do not have rest periods.

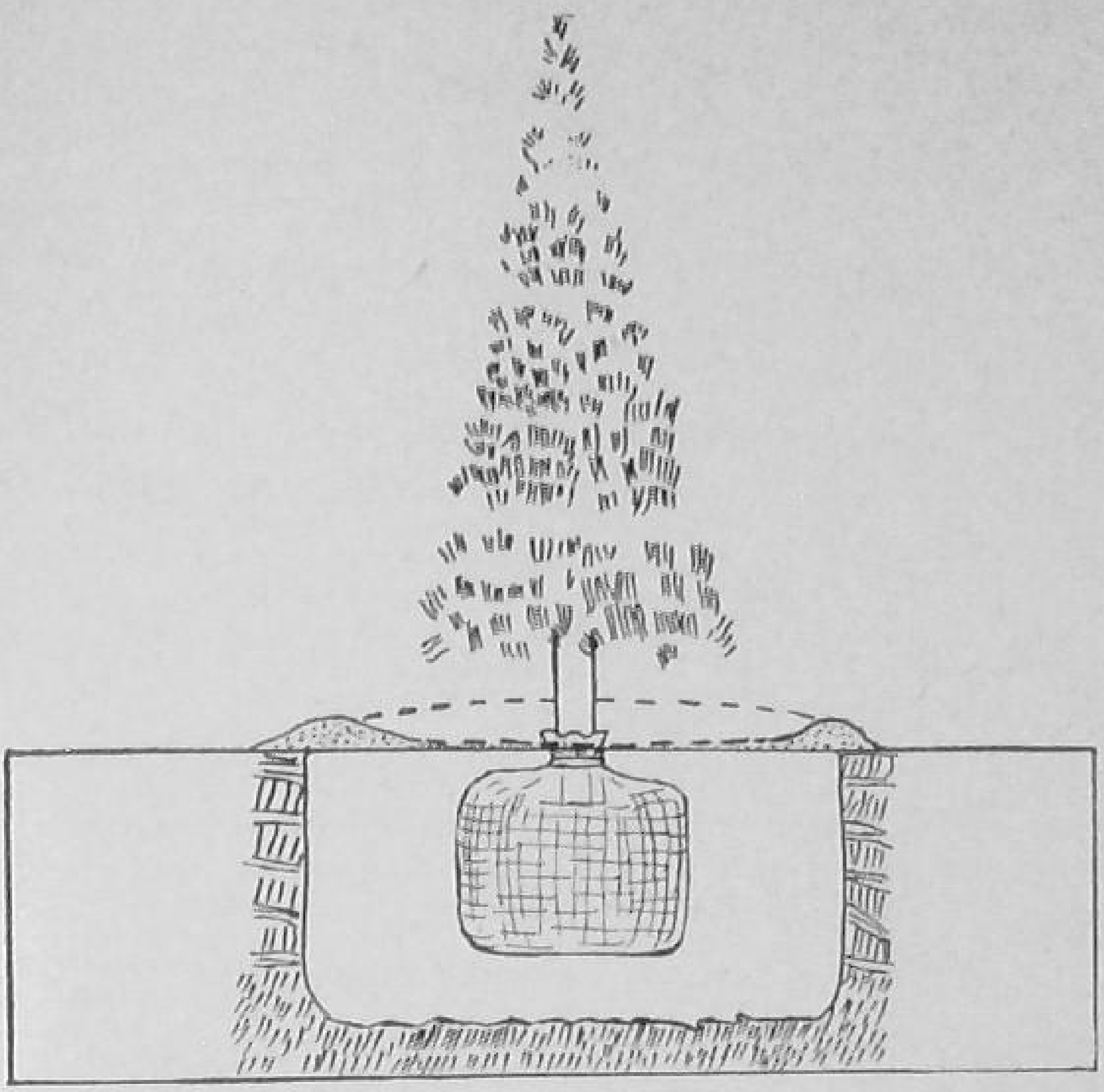


FIG. 68. A balled and burlapped evergreen tree. Operations: 1, dig large hole and loosen subsoil at bottom; 2, fill hole with soil to set tree at proper depth; 3, untie cord around trunk and cut burlap in several places; 4, complete filling hole with soil using light firming; 5, construct water basin; 6, apply water.

USE OF WAX

Recent investigations have shown that the use of emulsified waxes facilitate the rate of recovery of trees and shrubs in full leaf. These emulsified waxes are soluble in water, relatively permeable and colorless, and can be applied to plants in the form of a spray. The principal purpose of the wax is to reduce the rate of transpiration with no reduction in photosynthesis. Thus, the outgo of water is reduced, wilting is avoided, and recovery from transplanting is facilitated. Applications of the emulsion to trees at the time of digging and again after setting facilitate plant recovery. For example, in 1934 a nursery in Michigan transplanted 22 moderately large elms in full leaf. Of these trees 11 were sprayed with wax emulsion and 11 were sprayed with water only. Of the 11 trees sprayed with the emulsion 10 recovered and of the 11 trees sprayed with water only one survived the operation.

Questions

1. What is the immediate effect of transplanting?
2. Show how transplanting retards cell division and cell enlargement.

3. In the same environment a plant with a large leaf surface has a greater outgo of water than a plant with a small leaf surface. Explain.
4. Whenever possible, herbaceous plants should be transplanted in the seedling stage. Explain.
5. In general, moderately vigorous herbaceous plants recover more quickly from transplanting than extremely vigorous herbaceous plants. Explain.
6. Plants with a slow rate of top growth recover more rapidly from the check in growth due to transplanting than those with a fast rate of top growth. Explain.
7. Given two lots of tomato plants. Lot A was transplanted twice; lot B three times. Which lot recovered the more quickly from transplanting operations? Give reasons.
8. Tomatoes grown for early market in northern United States and for long distance shipment in southern United States are usually transplanted. Are they or are they not transplanted in each region for the same reasons? Explain.
9. Cucumbers require considerable care in transplanting, while cabbage does not. Explain fully.
10. Foggy weather is ideal transplanting weather for plants in full leaf. Explain.
11. Given two lots of plants. Lot A was transplanted in the morning; lot B in the late afternoon. Which lot recovered the more rapidly? Give reasons.
12. Given two lots of plants transplanted to flats in the greenhouse. Lot A was shaded; lot B was not. Which lot recovered the more rapidly from transplanting? Explain.
13. Given two lots of tomato plants grown in flats. Lot A was blocked; lot B was not. In your opinion, which lot would recover more rapidly from the check in growth incident to transplanting? Explain.
14. How does hardening of herbaceous crops facilitate recovery from transplanting?
15. Show how hardened cabbage plants withstand subfreezing temperatures while hardened tomato plants cannot.
16. Given two lots of tomato plants. Lot A was hardened before transplanting; lot B was not. In your opinion which lot would recover the more rapidly from transplanting? Explain.
17. In the Charleston-Beaufort trucking district of South Carolina, two crops of cabbage are grown. The first crop is started in August and the seed is sown directly in the field. The second crop is started in December and the plants are set in the field. Give reasons for the differences in starting the two crops.
18. In general, the deciduous orchardist transplants his trees when they are without leaves. Explain.
19. Given two lots of one-year-old seedling peach trees. Lot A is in full leaf; lot B is dormant. Which lot is likely to recover the more rapidly from transplanting? Explain.

20. In most districts of southern United States, woody plants are transplanted in the fall and in northern United States they are transplanted in early spring. Explain.
21. Evergreens are usually transplanted with a ball of earth. Explain.
22. Show how wax emulsions facilitate recovery of trees in full leaf from the check due to transplanting.

Assignment 18

CULTIVATING

Weeds markedly decrease yields. They use carbon dioxide, light, water, and nutrients which would otherwise be used by crops. There are only so much of these materials to go around. According to a recent survey of the United States Chamber of Commerce, weeds cause farmers and gardeners in the United States an annual loss of 3 billion dollars. Thus, the practical importance of weed control is obvious.

Table 21

EFFECT OF WEEDS ON THE YIELD OF GARDEN BEETS GROWN AT ITHACA, NEW YORK, FROM 1920 TO 1925

Number of Roots per Plot		*Average Weight of Roots (Pounds)*	
Cultivated Plot	*Weed Plot*	*Cultivated Plot*	*Weed Plot*
381	149	60.6	9.3

The effect of weeds on the growth of garden beets is presented in Table 21. The tests were conducted at Cornell University from 1920 to 1925 inclusive. In one set of plots the weeds were allowed to grow. In another comparable set they were controlled by cultivation. Experiments with other crops (carrots, cabbage, onions, celery, potatoes, and tomatoes) produced similar results. Many scientists believe that even a small growth of weeds will reduce yields from 20 to 50 per cent. Successful growers keep their gardens and fields practically free from weeds.

Cultivation or stirring of the upper 1-inch or 2-inch layer of soil creates a loose layer called a soil mulch. Is the maintenance of a soil mulch bene-

ficial in the absence of weeds? To secure information on this question, a series of experiments were conducted at Ithaca and River Head, New York. At Ithaca, beets, carrots, onions, celery, and tomatoes were grown for a period of 5 years, and at River Head potatoes and cabbage were grown for 4 years, carrots for 5 years, and tomatoes and beets for 7 years. One set of plots was cultivated once each week and another set was scraped with hoes. No weeds were allowed to grow in either case. The results (not presented) show that there were no practical differences in the marketable yields of the various crops due to the different treatments. In other words, cultivation in the absence of weeds did not increase the yield of the crops tested. Since the marketable yield is the main criterion by which any practice should be evaluated, and since cultivation in these experiments failed to increase the marketable yield, the maintenance of a soil mulch on the types of soil used in the experiment is of doubtful value.

Influence on Soil Moisture. Does cultivation conserve soil moisture in the absence of weeds? In the cultivation experiments conducted at Ithaca, New York, and discussed in the preceding paragraph, the moisture content of the cultivated and scraped plots was determined. Of a total of 280 determinations made over a period of 5 years, the cultivated plots had the higher moisture content in 188 comparisons; the scraped plots had the higher moisture content in 79 comparisons; and the cultivated and scraped plots had the same moisture content in 13 comparisons. Furthermore, the differences in moisture content between the cultivated and scraped plots were very small. As previously stated, any practice should be evaluated in terms of marketable yield. In the experiments cited there was no relation of average moisture content to yield of the crops except in the case of celery. With this crop the cultivated plots had the higher moisture content and the higher yield. With the other crops, cabbage, carrots, onions, and tomatoes, the cultivated plots did not always have the higher moisture content. Under some conditions, cultivation resulted in loss of moisture when conservation might have increased the yield. Under other conditions, cultivation resulted in conservation of moisture when a lower water content might have increased the yield.

Influence on Soil Temperature. How does cultivation influence soil temperature? For the most part, heat is conducted into the soil through the soil particles. For heat to pass from particle to particle, they must be in contact with each other. Since a compact soil surface has more particles in contact with each other than a loose surface, more heat will be conducted through the compact soil than through the loose soil. Thus,

stirring of the topsoil by cultivation will lower soil temperature. However, the results of many experiments show that the lowering of soil temperature by cultivation is very slight, not more than 3° to 5° F. at the most.

Influence on Nitrate Formation. How does cultivation influence the formation of nitrate-nitrogen? As stated before, nitrate-nitrogen is made by certain soil organisms. Since cultivation modified soil temperature and moisture supply to a small extent, its effect on the activity of soil organisms will be slight also. Breaking the crust of heavy soil undoubtedly facilitates the exchange of carbon dioxide and oxygen. Thus, it may increase nitrification. However, the experiments at Ithaca, New York, showed no relation of cultivation to nitrate formation and to the yield of the crops and soil tested. The crops were beets, carrots, cabbage, celery, onions, and tomatoes, and the soil was a Dunkirk gravelly loam.

Cultivation Tools. Cultivators are fitted with various types of attachments, depending on the kind of cultivation to be done. In general, there are two types: (1) Scraper and (2) toothed. The toothed types cultivate relatively deep, and the scraper types cultivate relatively shallow. Each type has its specific purpose. Examples of the toothed type are the cultivator steels. These vary in width from 1 to 4 inches. In general, narrow steels are used for fine work and broad steels for coarse work. Examples of the scraper type are one-sided sweeps, two-sided sweeps, and horizontal blades.

The Cultivation Program

The frequency and depth of cultivation of any particular crop depends largely on the following factors: (1) The frequency with which crops of weeds become established, (2) the amount of top and root growth of the crop plants, and (3) the soil type.

Weed Establishment. The best time to kill weeds is when they are young. During the seedling stage most weeds are easily displaced or covered with soil, and they have not become sufficiently large to seriously compete with the crop for carbon dioxide, light, water, and nutrients. Obviously, with other factors equal, the number of cultivations will depend on the frequency with which crops of weeds become established. For this reason, a continuously moist soil usually requires a greater number of cultivations than a continuously dry soil.

Amount of Top and Root Growth. A direct relation exists between the amount of top growth a crop is making and the amount and extent of the root system. Thus, during the seedling stage the root system of any given

plant is relatively small and inextensive. As the plant continues to grow, the root system continues to grow also and with most crops it gradually becomes very extensive. Consequently, the first and second cultivations of any given crop may be relatively deep, particularly if the crop has been transplanted. Succeeding cultivations should be relatively shallow and proceed further from the plants to avoid cutting the feeding roots just beneath the surface. Certain authorities believe that if weeds are absent when herbaceous annual crops are half grown, cultivation should cease.

Soil Type. Certain experiments indicate that the type of soil should be considered in the cultivation program. In Ohio on Brookston soil, with corn as the test crop, cultivation had no value except that of weed control. On the other hand, on Miami soil cultivation, in addition to weed control, increased the moisture and nitrate supply. Since Brookston soils are loose and somewhat self-mulching, and since Miami soils are tight and somewhat self-crusting, benefits from cultivation in addition to weed control apparently depend to some extent on the type of soil. Thus, self-crusting soils growing the same crop in the same environment may require a greater number of cultivations than self-mulching soils.

Chemical Control of Weeds

Chemical compounds are used to control weeds in certain crops. The compounds are selective in their action. That is, they kill the weeds and do very little, if any, damage to the crop. In general, these compounds may be placed in two groups: (1) Toxins or poisons and (2) hormones or growth-promoting substances. The toxins kill the protoplasm by direct chemical action, and the hormones induce a rapid and uncontrollable rate of cell division. In other words, the plants literally grow themselves to death.

Toxic Compounds. Toxic compounds used are: (1) Dinitro compounds, (2) petroleum products, (3) cyanates, and (4) sulfuric acid.

Dinitro Compounds. These are: (1) Sinox, the sodium salt of dinitro-ortho-cresylate, and (2) Dow Selective, the ammonium salt of dinitro-ortho-secondary-butyl-phenol. Recent research indicates that these substances may have a place in the control of garden peas raised for the cannery. (The fields are seeded with grain drills; the planting is solid; and hence conventional cultivation is impractical.) Both compounds have been tested rather extensively with and without the activator—ammonium sulfate. The rate of application varies from 2 to 8 pints of the material in 80–100 gallons of water.

Petroleum Products. The petroleum products are stove oil, light fuel oil, kerosense, and Stoddard's Solvent. Of these, stove oil and Stoddard's Solvent are the most widely used. These materials are specific for the vegetable crops of the Umbelliferae family—carrots, celery, and parsnip. In other words, these crops are resistant to the effect of the oil and other plants—the weeds—are susceptible. At present, stove oil and Stoddard's Solvent are used extensively for the control of weeds in commercial carrot fields. In general, these materials are applied at the rate of 80 to 125 gallons per acre without dilution under low pressure (50 pounds per square inch), with fine, fan-shaped, spray nozzles, when the carrot seedlings have two to four leaves (see Figure 69).

Cyanates. The cyanates are cyanamide and potassium cyanate. Recent research indicates that cyanamide applied as a fertilizer in amounts of from 350 to 400 pounds per acre controls weeds in asparagus plantations and that potassium cyanate applied as a 2 per cent solution at 80 gallons per acre controls weeds in onion fields.

Sulfuric Acid. This compound has been tested extensively in onion fields in New York. In general, satisfactory control was secured with most weeds through the use of a 2 per cent solution applied at the rate of 80 to 100 gallons per acre. However, since sulfuric acid is highly corrosive, it requires extreme care in handling and the use of non-corrosive metals. In addition sulfuric acid does not kill purslane, lamb's quarter, or grasses.

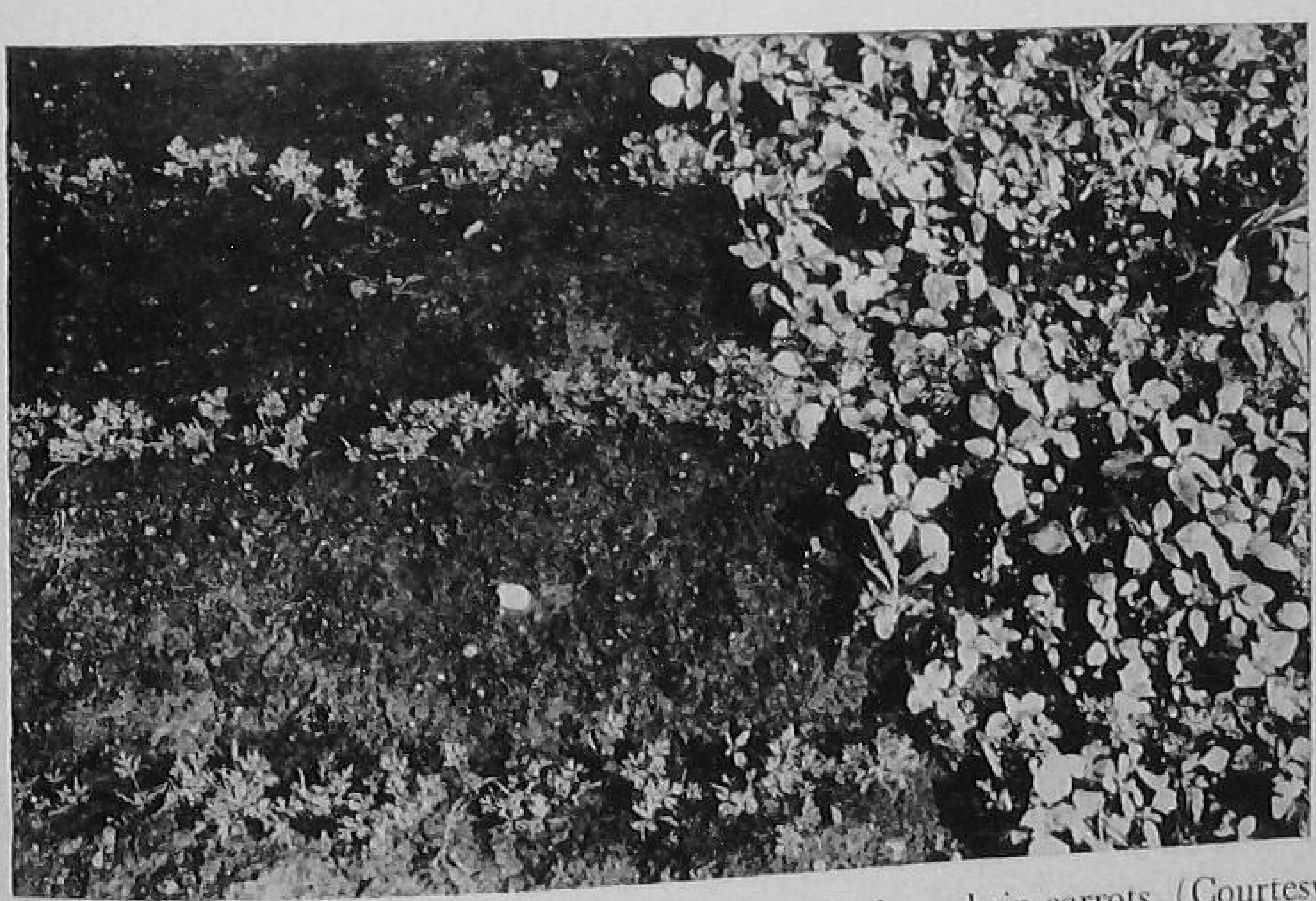


Fig. 69. Effect of a petroleum product on control of weeds in carrots. (Courtesy, W. H. Lachman, University of Massachusetts.)

FIG. 70. 2,4-D injury on cotton. The injured leaf in the center was sprayed with 6 ppm of a sodium salt of 2,4-D. (Courtesy, John T. Presley, Mississippi Agricultural Experiment Station.)

Hormones. The principal hormone used is dichlorophenoxyacetic acid and its derivatives. These are commonly known as 2,4-D. The derivatives may be placed in two groups: (1) Those which are soluble in water—the sodium, ammonium, and amino salts of the acid—and (2) those which form emulsions with water—the esters of the acid. In general, the water-soluble derivatives are somewhat less rapid in their action than the ester derivatives. This hormone and its derivatives have been tested rather extensively. Encouraging results have been obtained in the control of many broad-leaved weeds in lawns and golf courses and in fields of certain vegetables and flowering plants—sweet corn, potatoes, and gladiolus. However, unless 2,4-D is properly used, injurious effects are likely to occur (see Figure 70).

PREPLANTING TREATMENTS

In preplanting treatments the land is prepared for planting; weeds are allowed to grow until they have become established; then the seed of the crop is planted and immediately after the chemical is applied. Many chemicals have been tested—Sinox, Dow Selective, the volatile oils, cyanates, and 2,4-D and its derivatives. Promising results have been obtained with many herbaceous crops—onions, potatoes, carrots, and sweet corn.

MULCHING

Mulching is the application of certain materials to the surface of the soil. Materials usually used are: straw, pine needles, peat, leaves, and sawdust. The primary purpose of mulching is to promote the production of high yields. These high yields may be secured through the control of weeds or by modifying the soil temperature, the moisture supply, or the nitrate-nitrogen supply. These in turn influence the growth and marketable yield of the crop.

The use of straw has been tested in the growing of warm-season vegetable crops. It seems to be particularly beneficial to tomatoes during hot-dry weather. In experiments in Pennsylvania in 1931, tomatoes mulched with straw produced 21.4 tons of ripe fruit per acre, and unmulched tomatoes produced 15.1 tons per acre. There was very little rain during May, June, and July. Similar results have been secured in Mississippi. Straw or marsh hay are the materials used.

The use of needles of the longleaf pine as a mulch for strawberries is a standard practice of strawberry growers in the vicinity of Hammond, Louisiana, the center of the largest strawberry producing district in the country. The pine needles conserve soil moisture and lower soil temperature during the hot summer months and keep the fruit comparatively clean during the picking season. The needles are gathered in woods adjacent to the strawberry fields.

Peat is used primarily on lawns, golf greens, about trees and shrubs, and for certain crops in the greenhouse. Where water is used for irrigation, as on the home grounds and on lawns and greens of country clubs, the use of peat is very satisfactory.

Questions

1. The main criterion of the value of cultivation should be its effect on the marketable yield. Explain.
2. What is the primary purpose of cultivation?
3. Weeds markedly decrease yields. Give four reasons.
4. Cultivation may actually lower the soil temperature. Explain.
5. Cabbage has an extensive root system. When the heads begin to form, the roots occupy all of the fertile soil. Outline a cultivation program for your particular section of the country.
6. Celery has a sparse root system. The roots occupy soil not more than 6 inches from the basal portion of the plant. Outline a cultivation program for your particular section of the country.

7. In general, rains are light in intensity in the North and heavy in intensity in the South. Would the cultivation program for a crop of tomatoes be the same for each region? Give reasons.
8. Would the cultivation program for a crop of tomatoes be the same in central Mississippi as in south Texas? Explain.
9. Given two types of soil. Soil A is self-mulching; soil B is self-crusting. Which soil requires continuous cultivation? Explain.
10. In general, the tooth type of cultivator is used when the crop is in the seedling stage. The scraper type is used when the crop is more than half grown. Explain.
11. Given two rains. Rain A is 0.5 inches; rain B is 3.0 inches. After which rain is cultivation likely to be more beneficial? Explain.
12. A deep cultivation (2 to 3 inches) during the fruiting period of a crop of tomatoes or cantaloupes is likely to reduce the yield. Explain.
13. Given a wet-season during the period of head formation of a crop of cabbage. Show how deep cultivation would reduce the bursting of the heads.
14. Under what conditions would deep cultivation lower the rate of photosynthesis of a crop, and under what conditions would it have little effect? Give reasons.
15. How do toxic compounds and hormones differ in their action on plants?
16. What precautions are necessary in the use of 2,4-D?
17. What are preplanting treatments?
18. Why should preplanting treatments be very effective in weed control?
19. The mulching of tomatoes with straw in the North and South during the summer has produced beneficial results. Explain.

IRRIGATING

The Water Supply, Photosynthesis, and Yield. When the living cells of plants are in a state of turgor they are fully stretched. The guard cells are fully expanded, and the size of the stomata is at a maximum. With other factors favorable, the diffusion of carbon dioxide is rapid and photosynthesis is accordingly rapid. To maintain this condition, the amount of water going into a plant must, in general, equal the amount going out. If, for any reason, the amount going out exceeds that coming in, a chain of events is initiated which finally results in decreased photosynthesis, growth, and yield. The guard cells become flaccid; the stomata decrease in size; as a result carbon dioxide diffusion into the plant is limited, photosynthesis is accordingly limited, and yields and quality are low. Thus, when the intake is less than the outgo, the water supply becomes the limiting factor in plant growth. Note the relation of the amount of available water to yield in Figure 71.

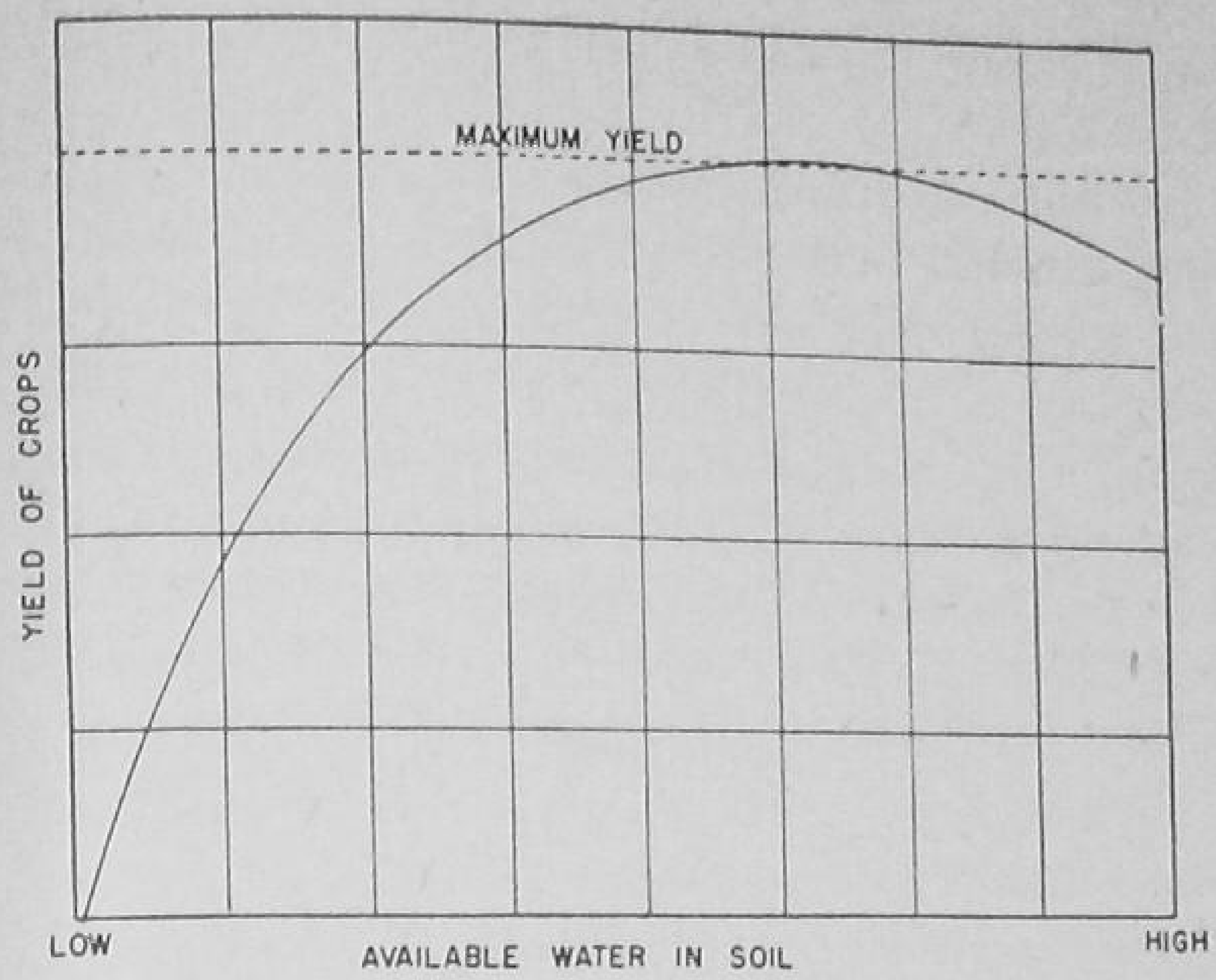


FIG. 71. Relation of amount of available water to yield. (Courtesy, Thorne, D. W. and Peterson, H. B.: "Irrigated Soils," Philadelphia, The Blakiston Company, 1949.)

Natural Supplies of Water. The principal source of water is rain or snow. The annual amount and distribution of rain or snow in the United States varies greatly from region to region within any season and from season to season within any region. Based on the average annual precipitation, the United States may be divided into three more or less overlapping regions: (1) The arid—less than 10 inches, (2) the semi-arid—from 10 to 30 inches, and (3) the humid—from 30 to 85 inches. The arid region is a relatively small area and, in general, comprises the Salt River Valley of Arizona, the Coachella Valley of California, and parts of Nevada and southern Idaho. The semi-arid region includes the western half of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas, the eastern half of Washington and Oregon, most of Idaho and California, and practically the whole of Montana, Wyoming, Colorado, and Utah. The humid region is the largest area and comprises the eastern half of the United States and the coastal sections of Washington and Oregon. Within the eastern half of the country, the mean annual precipitation varies from 30 inches in Maine to 60 inches in southern Louisiana, Mississippi, Alabama, and parts of Florida, and to 80 inches in the mountain section of western North Carolina and northern Georgia. The wettest places in the country are certain areas in the Puget Sound District of Washington with an annual precipitation of approximately 120 inches. Study the precipi-

tation data in Figure 72. Note the marked differences in rainfall in many places of the country.

Is the rain from year to year adequate for the growth of crops in each of these regions? Since from 10 to 30 inches of rain is necessary for the growth and development of most horticultural crops, the rain in the arid and semi-arid regions is entirely inadequate. Hence applications of water are necessary. In fact, irrigation of the crops of these regions is considered the most important cultural practice, and the value of the land is determined by its accessibility to an abundant source of water. In these regions laws and regulations governing the use of irrigation water have been established. In fact, the crop-producing capacity of the arid and semi-arid regions is governed largely by the amount of water available and not by the inherent fertility of the land.

What is the situation in the humid region? The records show that the rainfall in this region is entirely adequate. However, crops growing in this region frequently suffer from lack of water. In other words, the rains do not always come when they are needed. Every year in some district there is a period of drought. This period may exist for 1 or 2 weeks only; yet

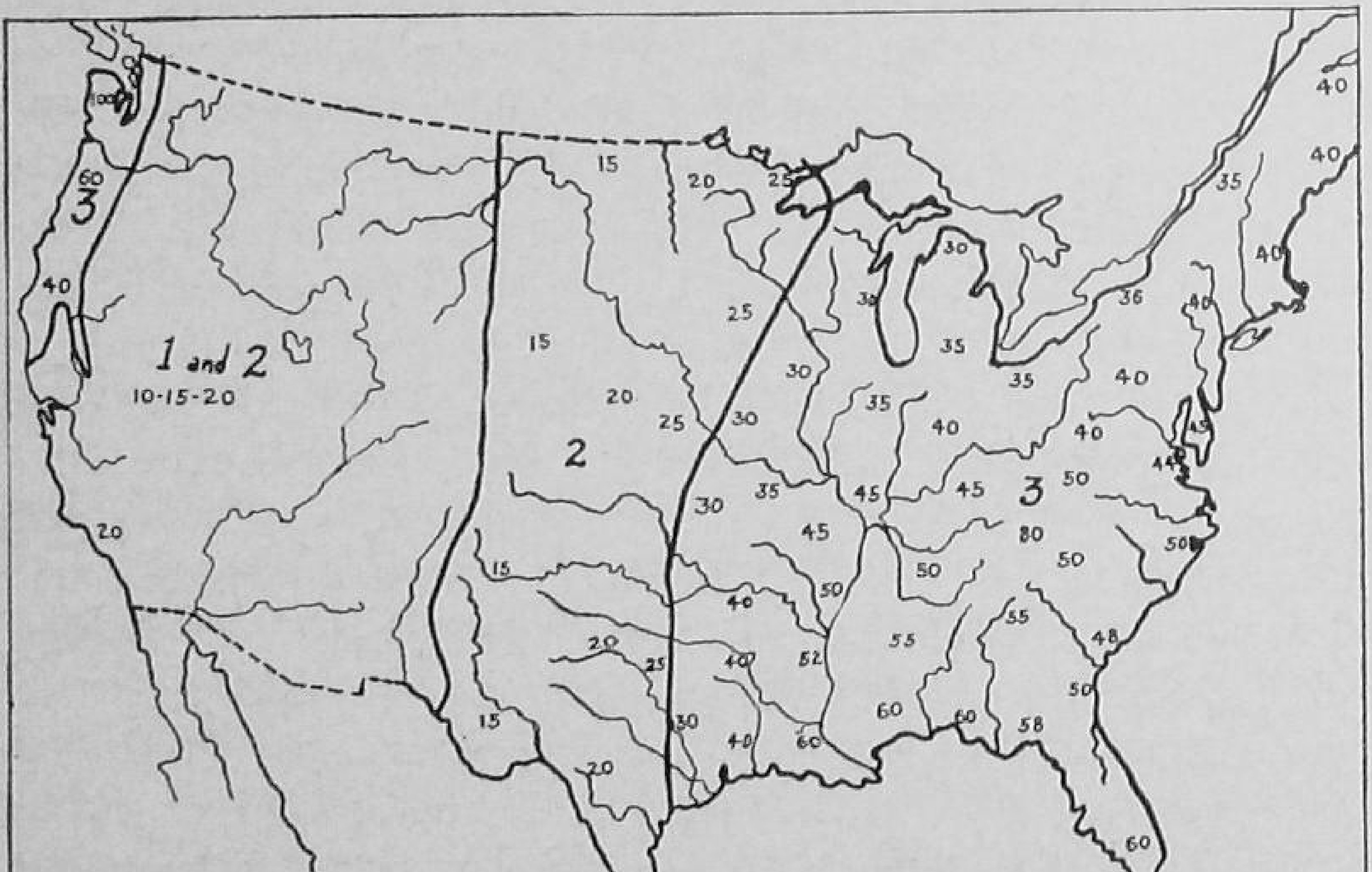


FIG. 72. Arid, semi-arid, and humid regions of the United States. (1 and 2) Mostly arid. (About 10 inches per year with semi-arid districts scattered throughout the area.) (2) Semi-arid (15–30 inches per year). (3) Humid (30–100 inches per year.)

it may come at a time when crops need rain badly. For example, from 1919 to 1939 there were 127 droughts in the humid regions of the United States. This is an average of six droughts per year. These droughts varied in length from 10 to 53 days. As another example, from 1910 to 1947, a period of 38 years, 42 per cent of the 226 day frost-free growing period at State College, Mississippi, had insufficient rain. As previously stated, droughts induce water deficits within the plant. This in turn lowers the rate of photosynthesis. This in turn decreases yield and quality and upsets the normal marketing period of the crop. Thus, since the rainfall is adequate, many growers are storing the water while it is not needed and applying it when it is needed. Consequently, applications of water in the humid regions are becoming increasingly common on orchard crops, vegetable crops, flower gardens, lawns, and golf courses.

Sources of Irrigation Water. The principal sources of water are streams, lakes, wells, ponds, reservoirs, and municipal water supplies. In the arid and semi-arid regions, the source of water is generally above the land to be irrigated and the water is carried over the land by gravity.* This water is derived from the snow precipitated on the mountains by the moisture-laden winds from the west and northwest. Thus, growers of horticultural crops are vitally interested in the annual snowfall in these regions. In the humid region, the source of the water is usually below the level of the land to be irrigated and pumps are necessary to lift the water. As with growers in the arid regions, growers in this region are interested in the annual precipitation, since this rainfall maintains the lakes, streams, ponds, reservoirs, and surface wells.

Water suitable for irrigation is moderately to slightly acid and free from appreciable quantities of salts. In districts where the water is quite alkaline, it is acidified to prevent the formation of highly alkaline soil. Chemicals generally used are sulfuric acid and phosphoric acid. The Ohio and Michigan Experiment Stations have developed machines for the acidification of water for greenhouse use.

Methods of Applying Irrigation Water

There are three more or less distinct methods by which water is applied to the land and crops. These are: (1) Surface irrigation, (2) sub-irrigation, and (3) spray irrigation. Each method has advantages and disadvantages.

*The western half of the San Joaquin Valley of California and the winter garden area and Rio Grande Valley of south Texas are exceptions.

Surface Irrigation. Surface irrigation is the application of water directly over the surface of the land. In general, this method of irrigation requires a gentle slope, a deep compact soil, and plentiful supplies of water. It is not adapted to rolling land nor to land which has shallow topsoil. For these reasons surface irrigation has extensive application in the arid and semi-arid regions of the country. Two systems of surface irrigation are used: (1) Border or basin and (2) furrow.

For *border irrigation* the land is leveled, if necessary, and bordered. The borders vary from 6 to 8 inches in height, generally follow the contours, and run in both directions. This method is commonly used to irrigate orchards in California and spinach in south Texas.

For *furrow irrigation* the land is leveled or ridged and furrowed. The furrows vary from 4 to 10 inches in depth and follow the contours of the land. This method is commonly used to irrigate most row crops in the arid and semi-arid regions. In fact, the many horticultural crop industries of the West have been made possible by the use of man's engineering skill to apply water to the land in this region.

Under certain conditions and with certain horticultural crops, furrow irrigation has produced profitable returns in the humid East. For example, in 1937 the Illinois Experiment Station irrigated by the furrow system 4 acres of tomatoes, and allowed a similar area to remain unirrigated. (The growing season for tomatoes in central Illinois extends from June to October.) The rainfall during the period of the test was well distributed, and only one irrigation was given to the irrigated area. The harvest season extended from August 18 to October 4. The once irrigated plot produced 521 baskets of marketable tomatoes, and the non-irrigated plot produced 311 baskets. Thus, the increased yield due to the one irrigation was 210 baskets of tomatoes. These tomatoes had a market value of $51.20. The cost of irrigating the 4 acre plot, including labor, fuel, and equipment, was $16.91, leaving a net gain of $34.29. Thus, irrigation was profitable during one of the best seasons for growing tomatoes in Illinois. Many other examples showing the value of supplementary irrigation in eastern United States could be cited. Note the position of the water stream in the furrow-irrigated orchard in Figure 73.

Sub-Irrigation. Sub-irrigation is the application of water below the surface of the land. Soils adapted for sub-irrigation consist of: (1) An impervious lower layer to hold the water against the force of gravity (clay or hardpan), (2) an open, porous, intermediate layer to act as a reservoir for water (sand or sandy loam), and (3) a finely textured top layer to

FIG. 73. Furrow irrigation of peach orchard. The water is applied in the terraced channels (below the trees), and in the contour furrows (above the trees). (Courtesy, Soil Conservation Service, U.S. Department of Agriculture.)

facilitate capillary action (fine sandy loam, silt loam, or peat). Sub-irrigation is used extensively in the celery district near Sanford, Florida, and in the onion and celery districts of Michigan and New York. In Florida the water is obtained from artesian wells and is conducted through lines of 3-inch drain tile placed 18 inches deep and 24 feet apart. In Michigan and New York the soil, a slightly acid, highly decomposed muck, is drained by ditches and the height of the water table is controlled by a series of dams in the ditches.

Spray Irrigation. Spray irrigation is the application of water on the surface of the land in the form of spray similar to a gentle rain. This type of irrigation is adapted to all types of soils and to both level and rolling land and generally requires less labor and less water than surface irrigation. The various types of spray irrigation systems are classified according to the materials which carry the water. These are: (1) The stationary pipe, (2) the portable pipe, and (3) the porous hose.

THE STATIONARY PIPE SYSTEM. This system consists of non-portable parallel lines of galvanized iron pipes. The lines are usually placed 50 feet apart and are supported on low posts 3 to 4 feet high, or on high posts 6 to 10 feet high, or on a cable supported by posts 12 to 20 feet high. The high post system is more popular than the low post, since it allows teams and

tractors to pass under the pipe lines and utilizes the land to better advantage. Each line of pipe is equipped with nozzles and an oscillator. The nozzles are of two types: (1) Those which deflect and thus break the water into a fine mist (generally used in greenhouses) and (2) those which discharge the water in the form of a small stream (generally used outdoors). When water is running through the system, the oscillator turns the pipe through an arc of 60° to 90°. Thus, pipes equipped with oscillators require less attention and facilitate a more uniform and steady application of water than pipes not so equipped. This system of irrigation is used extensively by market gardeners and florists throughout the country. A trip to any of the large market garden districts will convince the student of its profitable use and application. Its main disadvantage is the high initial cost.

THE PORTABLE PIPE SYSTEM. This system consists of two types: (1) Horizontal nozzle lines and (2) light-weight rotary sprinklers. Horizontal nozzle lines are similar to those used in the stationary system. To irrigate a large area one or more lines are carried from place to place. They may be placed directly on the surface of the land or supported on boxes, carpenters sawhorses, or wooden tripods. Light-weight rotary sprinkling systems consist of feed lines with joints which are quickly assembled and taken apart. The sprinklers are mounted on the pipes and are spaced 20 to 40 feet apart, depending on the type of nozzle and the pressure of water used. The main advantage of the portable pipe system is the relatively low initial cost. This type of irrigation is becoming popular in the different

FIG. 74. Spray irrigation in a potato field. The water is applied by means of a portable sprinkling system.

regions of the country. Note the portable system in operation in Figure 74.

The Porous Hose System. This system consists of applying water through porous material. The hose is made of canvas or of other fabric with a tight weave. The water is forced in small drops through the holes. This type of irrigation seems to be particularly adapted to crops grown in narrow rows such as strawberries and on soils which absorb water slowly. A modification of the porous hose is the eyelet hose. The eyelets are placed at intervals of about 2 feet to give alternating streams. This system has been used successfully in the apple orchards of the Ohio Orchard Company, Milford Center, Ohio.

Applying Water. The amount of water that should be applied and the frequency of application depends largely on the leaf area of the crop, the rate of transpiration, and the rate of evaporation from the surface of the soil. As stated previously, the rates of transpiration and evaporation are influenced greatly by temperature, relative humidity, light intensity, and wind velocity. To utilize water to the best advantage, its application should be uniform and thorough. In other words, overwatering and underwatering should be avoided. Overwatering induces excessive leaching of nitrate-nitrogen and minerals, deprives roots and soil organisms of oxygen, and retards root penetration. Underwatering fails to supply water to the lower levels of the topsoil, induces the development of shallow root systems, and is wasteful of water. Very little experimental information is available on the irrigation requirements of horticultural crops grown in the humid East, in spite of the increasing use of irrigation equipment. Some authorities state that on the average 1 inch of water per acre per week should suffice for most crops.

Questions

1. State the prime function of water in plant growth.
2. Crops growing in dry soil produce low yields. Explain this from the standpoint of photosynthesis.
3. Plants in full leaf give off more water than plants without leaves. Explain.
4. The transpiration rate of plants while being spray irrigated is comparatively low. Explain.
5. For the same crop grown in comparable soils more water would be needed in the Southeast than in the Northeast or Midwest. Explain.
6. The mean rainfall in the humid East is sufficient for the growth of horticultural crops; yet these crops frequently produce low yields. Explain.

7. Distinguish between surface irrigation, sub-irrigation, and spray irrigation.
8. In furrow irrigation, the slope for sandy loams should be from 10 to 12 inches per 100 feet and for clay loams from 1 to 3 inches per 100 feet. Explain.
9. In the Imperial Valley, California, crops are raised for long distance shipment. The soil and the site are ideal for furrow irrigation. Give the topography of the land, the texture of the soil, the force used to carry the water to the land, and the relative amount of water available.
10. In the state of New Jersey, crops are raised for short distance shipment. The soil and the site are ideal for spray irrigation. Give the topography of the land, the texture of the soil, the force used to carry the water to the land, and the relative amount of water available.
11. Compare furrow irrigation and spray irrigation from the standpoint of adaptation to the region east of the Mississippi River.
12. In general, high post spray irrigation utilizes the land to better advantage and facilitates cultivation to a greater extent than low post spray irrigation. Explain.
13. Draw a soil profile which is particularly adapted to sub-irrigation.
14. Investigations in apple orchards in the Cumberland Shenandoah Valley have shown that drought during the period of fruit growth decreases fruit size and that irrigation has increased fruit size. Explain.
15. Many orchardists in the humid region of the country have found that irrigation pays. Explain.
16. Growers of vegetable crops for early market irrigate their high cash crops. Explain.
17. Irrigation systems are part of the necessary equipment of the commercial florist. Explain.
18. From your own observation and experience describe how the home grounds are supplied with irrigation water.

13

Pruning

Assignment 19

Pruning is a major horticultural practice. It is necessary for the successful production of tree fruits, grapes, small fruits, nut fruits, and many flower and ornamental plants. In general, pruning consists of the removal of parts of the top or root system of plants. Woody tissues are usually removed by means of sharp cutting instruments in order to make clean non-jagged wounds. Succulent tissues are usually removed by hand.

The object of pruning varies with the viewpoint of the pruner. Commercial orchardists, gardeners, and florists are interested primarily in profits. In other words they consider such factors as size, color, shape, or quality of flower or fruit only as these factors influence profits. On the other hand, amateur gardeners place costs and profits in a secondary category. They consider such factors as size, color, shape, or quality as important in themselves.

Both the stem and the root systems of plants are pruned. Since pruning the stem and pruning the root influence growth and development differently, they are discussed separately.

PRUNING THE STEM

All plants respond to removal of the top in two definite directions. Pruning the top: (1) Always reduces the total amount of growth which could otherwise be made and (2) always influences the vegetative-reproductive balance of the plant.

Total Amount of Growth Made. Numerous investigations have shown that pruning the top dwarfs the tree or plant. The removal of twigs of trees or stems of herbaceous plants removes carbohydrates and other materials already made and removes the leaves which would have contributed to further food manufacture. In other words, the removal of stems and leaves or of stems containing buds which would later develop into leaves reduces the machinery for food manufacture. This removal in turn reduces the total amount of food that can be made in any one season. For example, consider two branches of an apple tree. Each branch has four twigs of equal size and vigor and each twig has 50 leaf buds which later develop into 50 leaves. Suppose we remove one twig from branch A and none from branch B. Although the individual leaves on branch A will be somewhat larger than those on branch B, with other factors favorable, the 200 leaves on branch B will make more food during the season than the 150 leaves on branch A. Thus, at the end of the growing season branch B will have made a greater amount of growth than branch A. As a second example, consider two tomato plants. Plant A is pruned to a single stem, that is the laterals on the main axis are "pinched off" as soon as they begin to develop. Plant B is allowed to grow the natural way, that is, no stems are removed. During the fruiting period plant B will have the greater leaf area. This greater leaf area will manufacture a greater quantity of food and because of this greater quantity of food plant B will produce the greater number of tomatoes. As a third example, consider two chrysanthemum plants. Plant A is pruned to a single stem and plant B is allowed to grow in the natural way. Plant A will produce one large flower at the top of the stem, and plant B will produce a small flower at the top of each of several stems. The total weight of the several small flowers produced by plant B will exceed the weight of the single large flower produced by plant A. Clearly, the removal of healthy stems and leaves reduces plant size and yield and the total amount of growth that can be made.

Vegetative-reproductive Balance. What is the relative effect of pruning the stem on the vegetative-reproductive balance? This effect can be determined by a study of the influence of pruning the stem on the water supply and the nutrient supply, particularly the nitrogen supply. Since pruning the stem reduces some of the top, it reduces the transpiring surface. (Twigs removed during the dormant season would otherwise develop leaves in the spring.) This reduces the outgo of water in relation to the income. Thus, pruning the stem increases the water supply within the plant. Since abundant water within the plant promotes rapid cell division

and cell enlargement, with other factors equal, pruning the stem will promote vegetative processes to a greater extent than reproductive processes. In other words, under average conditions, pruning the stem promotes the vegetative phase—the production of stems and leaves—rather than the reproductive phase, the development of flowers and fruit or storage structures.

How does pruning the stem effect the nutrient supply and the vegetative-reproductive balance? Pruning the stem removes the number of growing points in the top. Thus, a greater supply of nutrients is available for the growing points that remain. Since abundant nutrients, particularly abundant available nitrogen, promote rapid cell division, pruning the stem promotes growth processes to a greater extent than reproductive processes. Thus, pruning the stem promotes those responses of the plant which require the utilization of carbohydrates such as the invigoration or stimulation of vegetative growth. Conversely, pruning the stem retards responses of the plant which require the accumulation of carbohydrates such as the formation of flower buds. This stimulation of vegetative processes and retardation of reproductive processes may or may not be desirable. Much depends upon the age of the plant and the type of growth the plant is making. If, for example, orchard trees are young and vigorous, pruning, if necessary, should be extremely light, since heavy pruning of the top will retard flower bud formation. On the other hand, if orchard trees are old and lacking in vigor, severe pruning of the top will help to promote vigor and effect rejuvenation.

Kinds of Top-pruning. There are two kinds of top-pruning: (1) Heading-back and (2) thinning-out. *Heading-back* removes the terminal portion of twigs, canes, or shoots and leaves the basal portion. *Thinning-out* removes the entire twig, cane, or shoot. In general, heading-back stimulates the development of more growing points than a corresponding thinning-out. How does heading-back stimulate the development of more growing points? The student should remember that terminal buds on shoots secrete growth-inhibiting hormones which are translocated to the lateral buds. These growth-inhibiting hormones prevent the development of the lateral buds. When the terminal bud is removed, as in heading-back, the formation and translocation of the growth-inhibiting substances cease and one to several lateral buds develop. Usually, the lateral buds just below a cut develop more and they in turn manufacture the growth-inhibiting hormones which prevent the development of the lateral buds farther down. Thinning-out does not have this effect as much as heading-back. Thus,

heading-back induces the compact, dense, or much-branched type of growth and thinning-out induces the open or rangy type of growth.

Pruning the Stem of Woody Plants

TREE TRAINING AND TREE FORMS

Training is a type of top-pruning. It is particularly important in the many tree fruit industries. Young trees are trained to develop a frame of scaffold limbs sufficiently strong to bear large crops of fruit without breaking. Thus, the development of strong crotches and well-spaced limbs is essential. Furthermore, since even a light pruning of young trees lengthens the time from planting to flowering and fruiting the practice should be efficiently performed. The various forms to which trees are trained are of three general types: (1) Central leader, (2) open center or vase, and (3) modified leader.

Central Leader. The central leader type of tree has a main branch and a series of well-spaced, "subordinate," lateral branches. Its main advantage is the development of strong crotches due to the interlacing of fibers at the junction of the limb and the trunk. Its main disadvantage is shading the interior of the tree. This shading weakens the central leader and thus shortens the life of the tree. Authorities state that trees of some varieties such as the Wealthy apple are trained rather easily to this form, while trees of other varieties such as the Rhode Island Greening apple are trained to this form with difficulty.

Open Center or Vase. The open center or vase type of tree has no main or central branch but a series of well-spaced, "coördinate," lateral branches. These laterals are given the same dominance by cutting them back equally each year. Practically the same number of leaves will develop on each branch. Thus, all the coördinate branches make the same growth each year. The main advantage of this form of tree is the penetration of sufficient light for fruiting of inner branches and the development of a low-headed tree. This facilitates pruning, thinning, spraying, and picking operations. Its main disadvantage is the development of weak, crowded crotches which frequently break under severe stress and strain such as the bearing of a heavy crop of fruit.

Modified Leader. The modified leader type of tree is a happy medium between the central leader and open center. During the period of training the central leader is cut back slightly and allowed to become dominant. The process of cutting back and selecting laterals is repeated until the proper

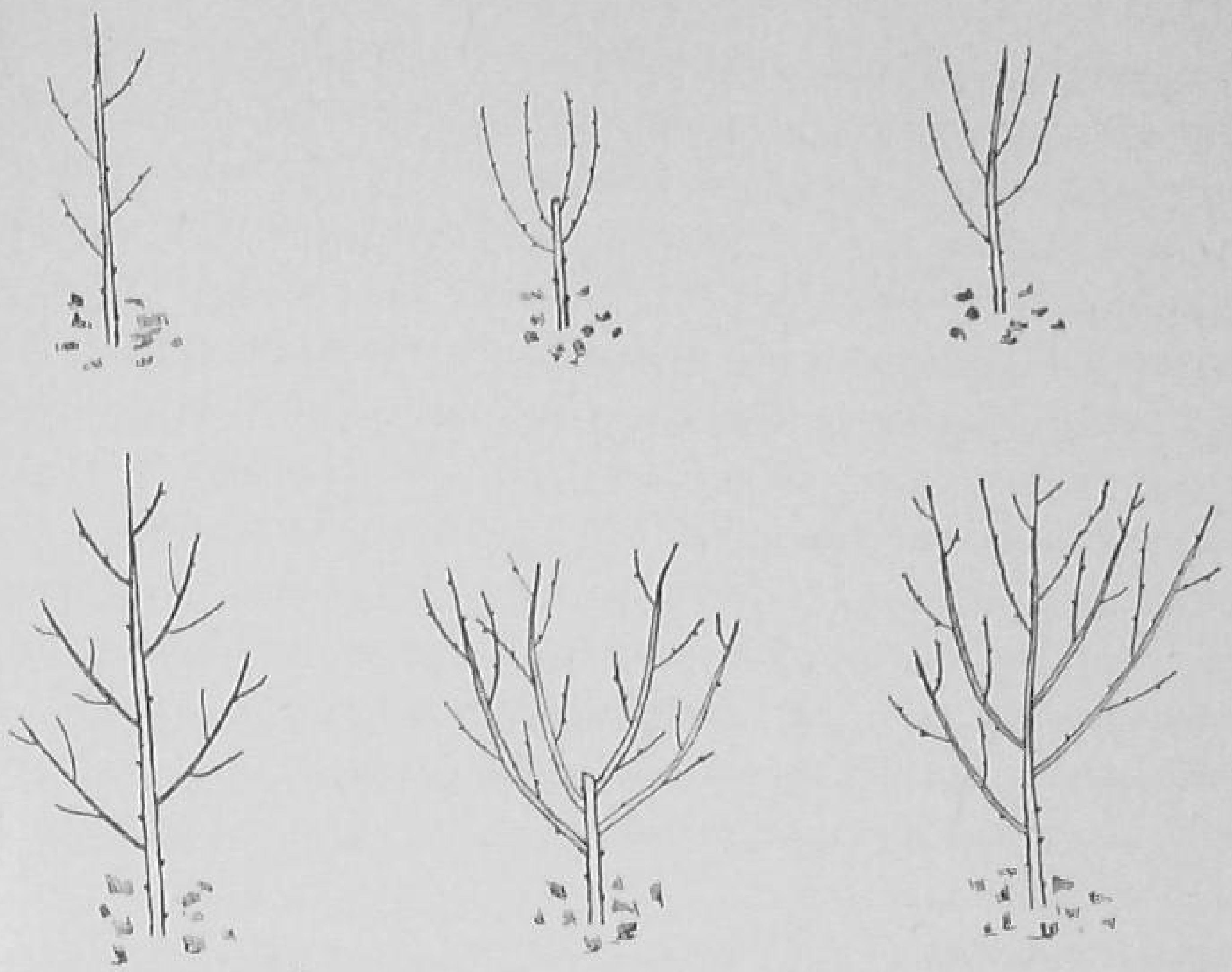


FIG. 75. Outline of scaffold branches of the three tree forms. (*Left*) Central leader. (*Center*) Open leader. (*Right*) Modified leader.

number and distribution of branches has been obtained. The central leader is then discontinued and the tree assumes a more or less rounded open top. In this way the modified leader type of tree has low and well-spaced limbs, well-distributed fruiting wood and is sufficiently close to the ground to facilitate the many orchard operations. Of the three types the modified leader is the most desirable for many tree fruits because it combines the most important advantages of the other types. Note the relative dominance of the main and lateral branches of each of the three types in Figure 75.

TOP-PRUNING SPECIFIC CROPS

Pome Fruits (Apple and Pear)

Fruiting Habit. A working knowledge of the fruiting habits of crops is essential to a proper understanding of pruning requirements. The fruit of the apple and pear is produced from mixed buds which, as a rule, are borne on very short lateral growths called spurs. These spurs are formed and come into bearing in the following manner. In the first spring some of the lateral vegetative buds make a short growth, usually ½ to 3 inches or more, and in late summer they develop a terminally situated mixed bud. In the second spring the mixed bud develops into a cluster of flowers,

makes a short growth and following fertilization one or two or more of the ovaries with the adjacent receptacles develop into fruit. In the third spring a lateral vegetative bud makes a short growth, usually ½ to 3 inches or more, as in the case of the first spring, and in late summer it develops a terminally situated mixed bud. Thus, a spur bears flowers and fruit in alternate years. However, new spurs are formed on the second, fourth, sixth, and even season's wood each year while the third, fifth, seventh, and odd season's wood bear fruit each year. Thus, certain spurs bear fruit in the even years and others bear fruit in the odd years. Thus, apple and pear trees bear fruit annually. However, should a frost, freeze, or some other adverse condition destroy the blossoms in any one year, carbohydrates will accumulate and a very heavy crop will be produced the following year. Such an unfortunate and undesirable condition exhausts the carbohydrate reserve and induces alternate bearing. Study the diagram of the fruiting habit of the apple in Figure 76.

Vegetative Period (1 to 4 Years). During the vegetative period the trees are trained usually to the modified leader type. Briefly, training consists of: (1) Heading-back to promote the development of lateral branches and a low-heading tree, (2) selecting well-spaced laterals to form the framework and removing the others, and (3) pruning the remaining limbs to regulate their growth so that each may occupy its relative proportion of space without interference. In general, one-year-old trees consist of a single stem called a whip. This whip is headed-back to a height of 42

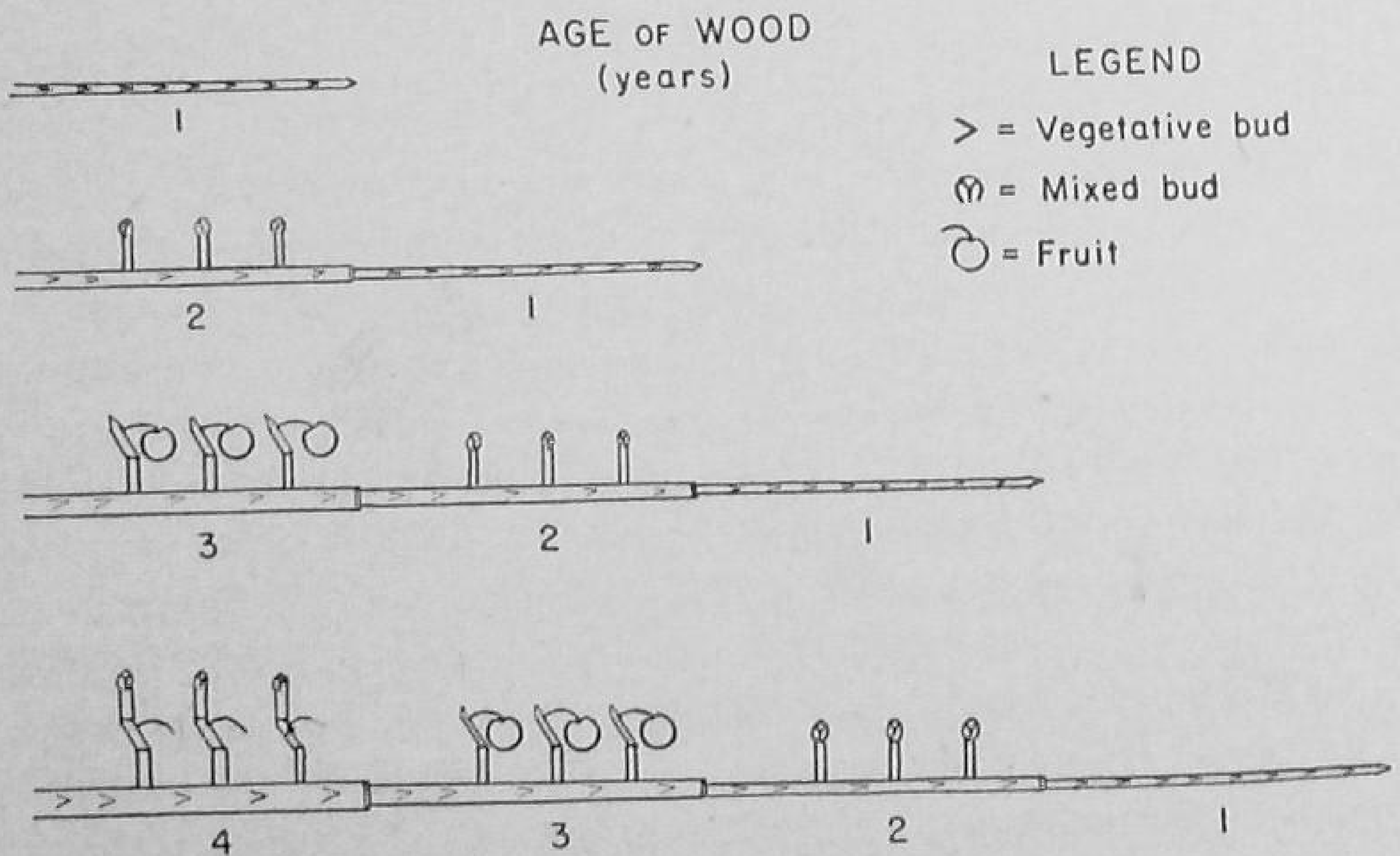


Fig. 76. Diagram of fruiting habit of the apple.

to 48 inches immediately after planting, and laterals are selected about 3 or 4 weeks after they have started growth in the spring, or during the next winter. In either case, four to six well-spaced lateral shoots are selected and the others are removed. The uppermost lateral usually achieves the greatest growth and is called the leader. In general, two-year-old trees have well-developed lateral branches. Immediately after the trees are planted, three to four well-spaced laterals are selected and the remainder are removed. Adequate spacing of the laterals is essential in order to keep them well distributed around the trunk (see Figure 77).

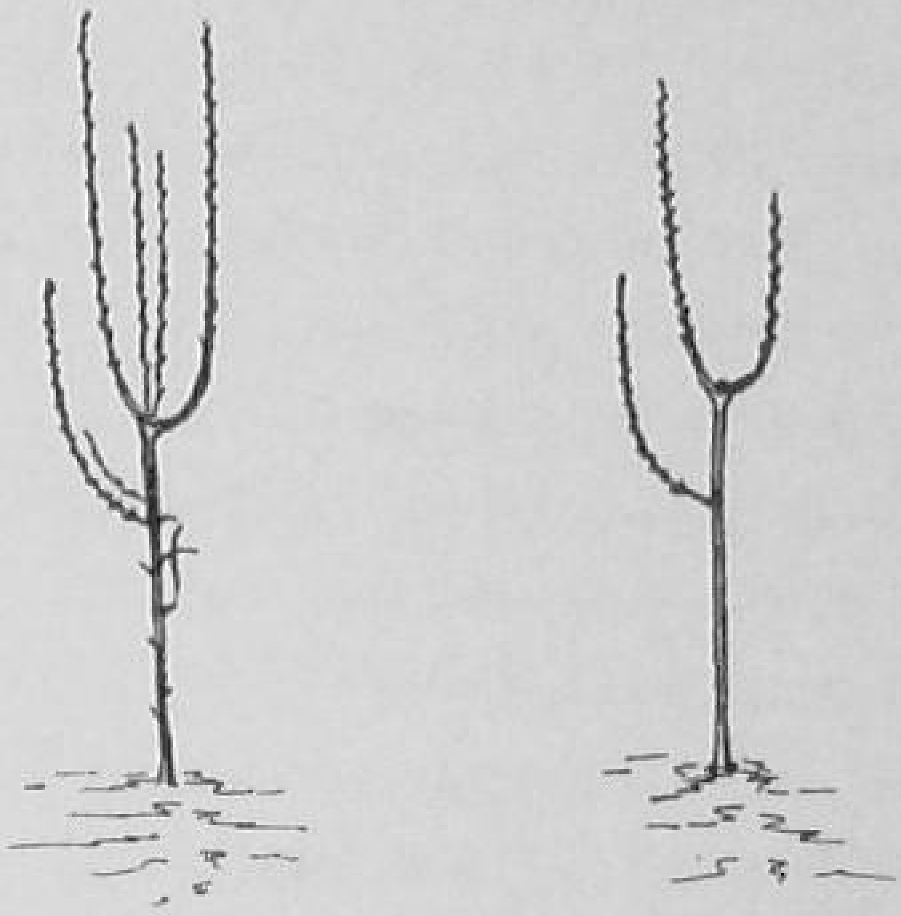


FIG. 77. Training a young apple tree. Which limbs were removed; which were allowed to remain; and which were headed back? (Redrawn from Training young fruit trees, *Iowa Agr. Ext. Ser. Pamphlet 102*, 1945.)

Transitory Period (3 to 4 Years). In the transitory period the trees are changing from an entirely vegetative phase to a period of alternating vegetative and reproductive phases. During this period the plants are pruned lightly since heavy pruning delays the onset of the fruiting period. In general, this pruning consists of removing undesirable suckers, dead or diseased wood, and of a light thinning-out of the top.

Fruiting Period (5 to 50 Years). This period is divided into two stages: (1) The early period and (2) the late period. During the early period the young bearing trees are vigorous and, in general, only corrective pruning is necessary. Corrective pruning consists of the removal of dead or diseased wood or undesirable parallel branches and in the regulation of the growth of the branches to permit the development of strong crotches. As the trees become older the development of small, weak branches becomes evident. Investigations at the Michigan Experiment Station have shown that a direct relation exists between the diameter of the four-year-old wood and the number, size, and quality of the fruit which it bears. In Michigan orchards, four-year-old wood ½ inch or more in diameter produced an average of ten fruits of good size and color; four-year-old wood from ⅜ to ½ inch in diameter produced an average of seven fruits of medium size and poor color; and four-year-old wood less than ¼ inch in diameter produced only three small, poorly colored fruits. Thus, the prun-

ing of mature bearing trees consists largely of the removal of four-year-old wood less than ¼ inch in diameter. Most of the thin, unproductive branches are found on the inside of the trees. The apple grower, therefore, in pruning his trees, leaves the thick productive branches and removes the thin unproductive ones.

Drupe Fruits (Peach, Apricot, Almond, and Plum)

Fruiting Habit. The fruit of the peach, apricot, and almond is produced from simple (unmixed) lateral buds which are mostly borne on one-year shoots. On these shoots leaf buds also are formed. The vigor of the shoot is associated with the kind and number of buds formed. For example: (1) Weak shoots produce relatively few nodes and very few flower buds per node, (2) moderately vigorous shoots produce a moderately large number of nodes and a large number of flower buds per node, and (3) extremely vigorous shoots produce an extremely large number of nodes and very few, if any, flower buds per node. Obviously, the number of flower buds formed depends on the vigor of shoot growth. Study the diagram of the fruiting habit of the peach in Figure 78.

Fruits of the plum and cherry are produced from simple (unmixed) lateral buds also. These lateral buds are borne on one-year-old wood and on spurs. Vegetative buds always terminate shoot and spur growth; therefore, the spurs are usually straight. Like the peach, moderately vigorous

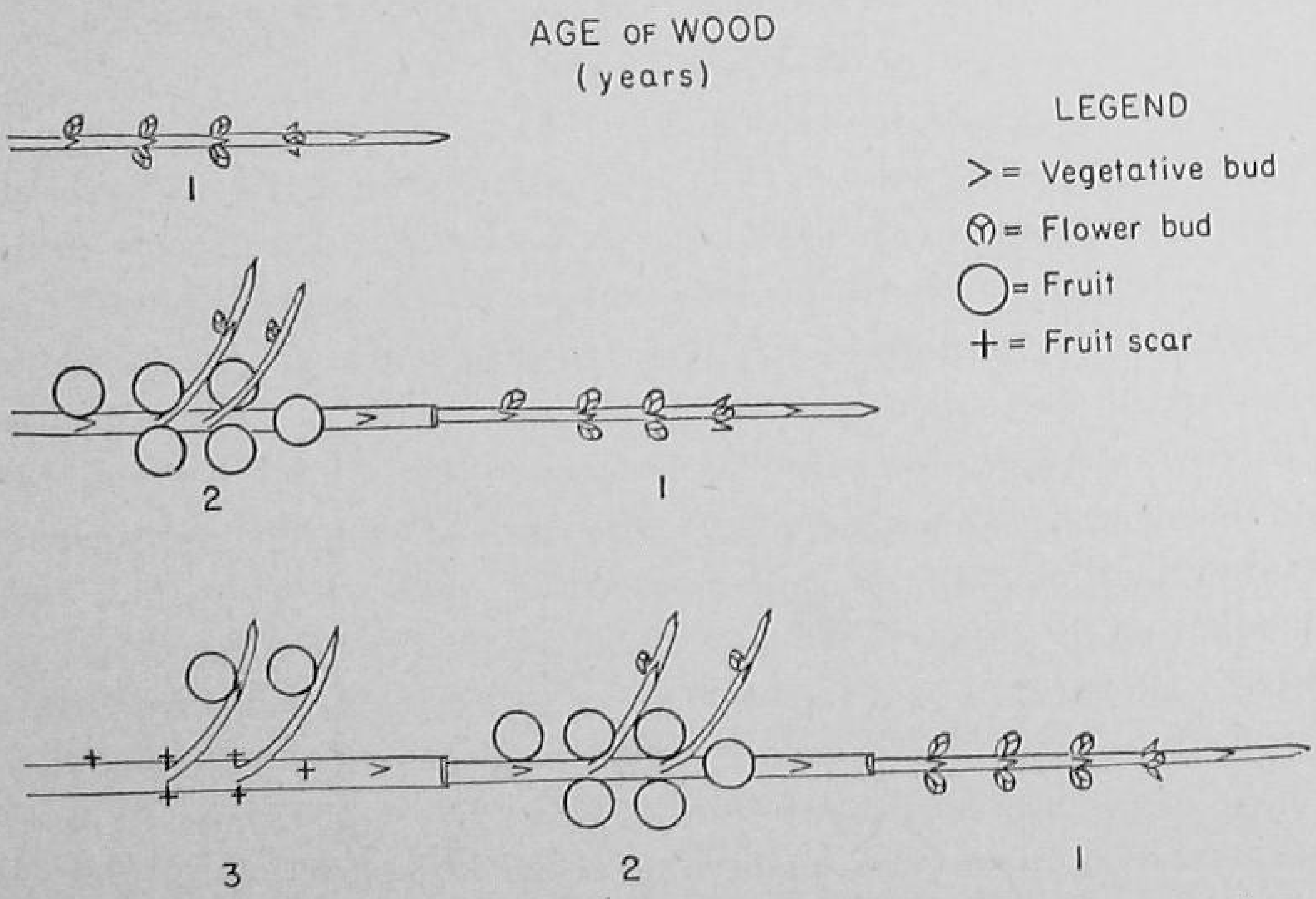


FIG. 78. Diagram of the fruiting habit of the moderately vigorous peach tree.

shoot growth of the plum and cherry increases the number of nodes, the number of flower buds and fruitfulness, while scant or overvigorous growth decreases the number of flower buds and fruitfulness.

The Peach: VEGETATIVE PERIOD (2 TO 3 YEARS). Although the peach has usually been trained to the open center form, recent investigations have shown that the modified leader type is more satisfactory. This type of tree is produced by means of "de-shooting." In the spring one-year-old trees are headed-back to a height of about 48 inches, and lateral branches are allowed to develop for a period of 3 to 4 weeks. At this time four or five well-spaced spirally arranged laterals are selected. The lower lateral occurs or is located at the 6- to 8-inch level with the upper lateral at the 48-inch level. This upper lateral becomes the leader. These four or five laterals will become the main scaffold branches of the tree. When June-budded trees are used they are allowed to develop a strong axis before "de-shooting" begins. In either case very light pruning is necessary after the first growing season. If any lateral endangers the dominance of the leader it is cut to an outside growing branch. At the end of the second year, secondary laterals are selected to form additional scaffold branches, and branches interfering with the development of the scaffolds are removed. At this time the dominance of the lateral may be removed by cutting back to an outside growing branch (see Figure 79).

TRANSITORY PERIOD (3 TO 8 YEARS). During the transitory period the trees start to bloom and produce fruit. As in the case of the apple and

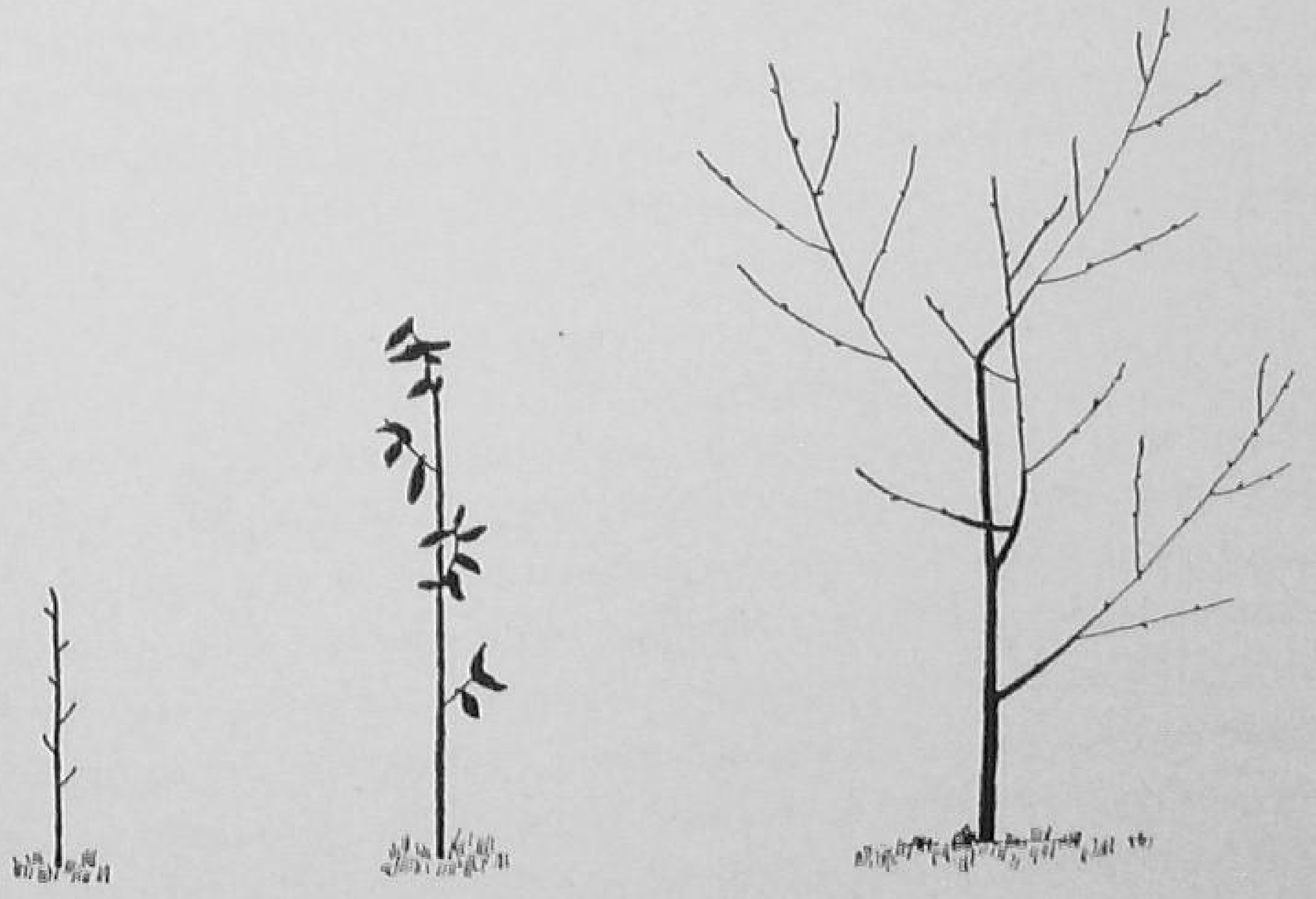


FIG. 79. Training of the young peach tree.

pear, light judicious pruning is essential during this period. Heavy pruning stimulates vegetative growth and delays fruiting. In general, the center of the tree is lightly thinned-out and the branches on the outside are lightly headed-back. If the dominance of the leader branch has not been destroyed, it is done during this period provided the secondary scaffold branches are well established.

FRUITING PERIOD (8 TO 20 YEARS). Since bearing peach trees usually produce more flower buds than can develop into fruit and since the fruit is borne on one-year-old wood, the essential pruning requirements are a reduction in the number of flower buds and a stimulation of new growth, well distributed throughout the tree. This can be accomplished by thinning-out weak, crowded branches and by heading-back the upright branches to an outside bud.

Cherry and Plum. Like the apple and pear the many kinds of cherries, sour, sweet, and Dukes; and the many kinds of plums, European, Japanese, and American are trained to the modified leader form of tree. In general, training involves the selection of three or four laterals and a leader. The laterals should be at least 1 inch apart and arranged around a main stem to prevent girdling of the trunk. During the transitory period light pruning, mostly of the thinning-out type, is necessary. With upright growing varieties attention is given to the development of lateral branches. During the bearing period the amount of thinning-out and heading-back varies with the species. In general, cherries require the least pruning since direct light is unnecessary for the development of the fruit, and the crop is seldom heavier than the tree can bear. The European plum requires more pruning than the cherry but less than the Japanese plum which requires less than the peach. In any case old trees are pruned more severely than young trees in order to renew the fruiting wood.

The Grape

Fruiting Habit. The fruit of the grape arises from mixed buds which are borne on one-year-old shoots called canes. These canes have developed during the previous season. Investigations have shown that fruiting of the grape is positively associated with vigor of the cane. In general, medium-thick canes (moderately vegetative) are more fruitful than thin (weakly vegetative) and thick canes (vigorously vegetative). For example, in Michigan and elsewhere canes of the Concord variety ¼ inch or slightly more in diameter at the fifth or sixth node are more productive than greater and smaller sizes at the same position. Thus, size of cane is an

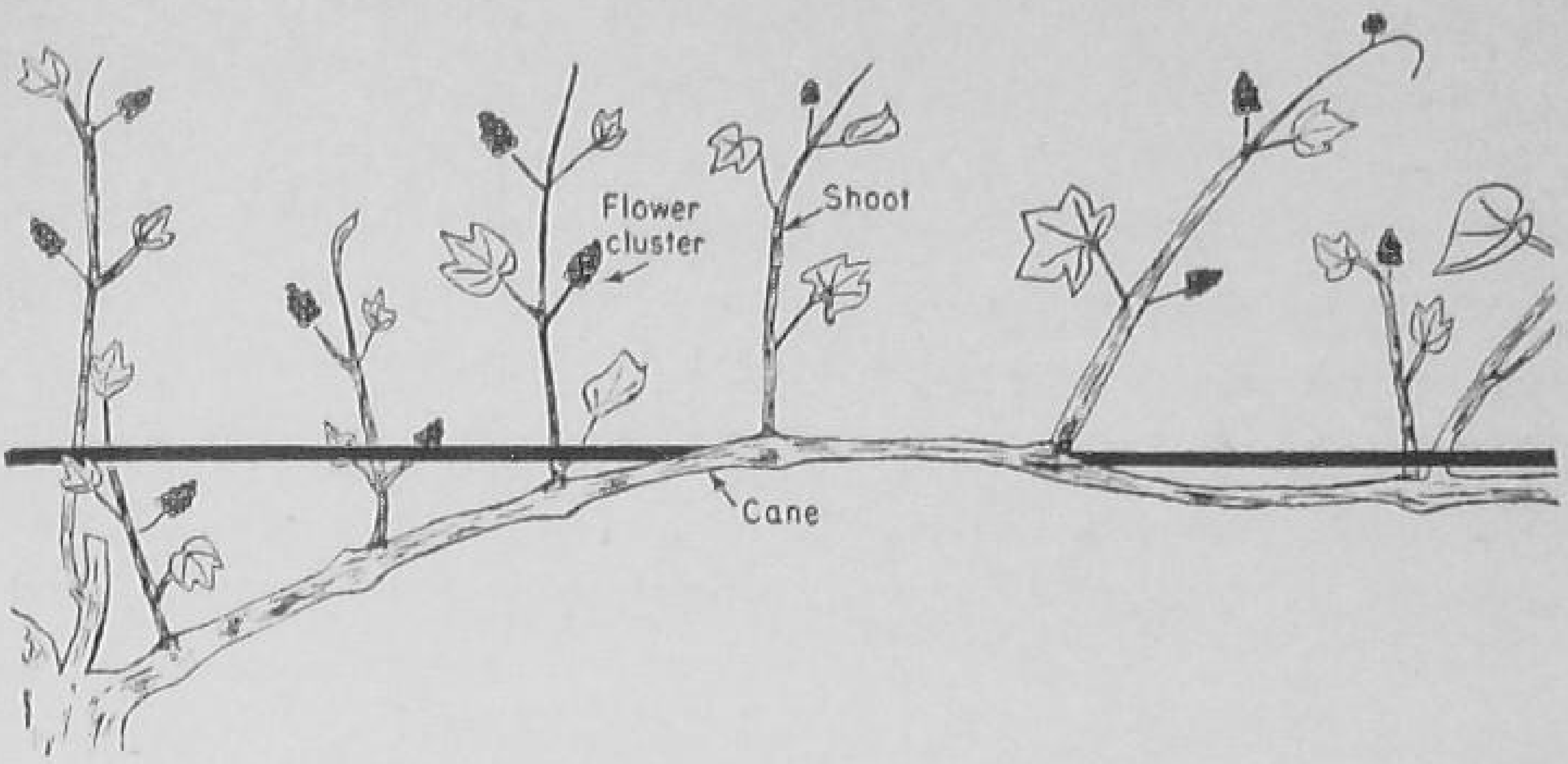


FIG. 80. Fruiting habit of grape. The fruit bearing shoots have just started their growth in the spring. Note the flower clusters opposite the leaves. (Redrawn from Sefick, H. J. and Clark, J. Harold: Pruning grapevines, *N. J. Agr. Exp. Sta. Cir. 423*, 1942.)

important consideration in productivity. Note the fruiting habit of the grape shown in Figure 80.

Pruning the Young Vine. Although grapes are pruned to various systems, the pruning requirements of the vine for the first, second, and third years are practically the same for all systems. The main operations are: (1) Cutting back the most vigorous cane to two or three buds and removing the remainder, (2) setting the plants in the vineyard, (3) tying the canes to a stake to permit close cultivation during the growing season, and (4) cutting back the most vigorous cane to two or three buds and removing the remainder during the dormant season. After the next season the vines are trained to the system desired.

Training Systems. Many systems are used in training grapes. Important systems are: (1) The single trunk four-cane kniffin, and (2) the fan.

The *kniffin system* requires a two-wire vertical trellis, the lower wire is usually 30 to 36 inches from the ground and the upper about 54 to 60 inches. A "permanent" trunk extends to the upper wire and from the trunk at the level of each wire two canes, one to the right and the other to the left, are selected each year. With vines of moderate vigor each cane is cut back to eight or ten buds with one or two more on the upper cane than on the lower. In addition four vigorous canes are selected and cut back to one or two buds to keep the fruiting wood reasonably close to the trunk. All other canes are removed. The four-cane kniffin system has the following advantages: (1) It is adapted to small home plantings and large commercial vineyards, (2) the trellis is relatively simple and easily con-

FIG. 81. Pruning the Labrusca grape, variety Portland. (*Left*) Before pruning. (*Right*) After pruning. (Courtesy, H. J. Sefick, Clemson Agricultural College.)

structed, and (3) cultural operations in the vineyard are facilitated. This system is more popular in commercial vineyards in the United States. Modifications of the four-cane kniffin system are the six-cane kniffin and the Y-shaped kniffin.

The *fan system* requires a two- or three-wire vertical trellis. No upright trunk is developed but instead a short trunk from which five to eight canes are trained to the trellis in the shape of a fan. The canes are cut back to contain from six to ten buds depending on the vigor of the vine. Additional canes, usually four to six, are cut back to one or two buds for the development of canes the following year. The main advantage of this system is that the number of canes can be regulated according to the vigor of the vine. Other systems are the three-wire canopy, horizontal arm, and overhead. The four-cane kniffin system for Labrusca grapes and for Muscadine grapes is shown in Figures 81 and 82, respectively.

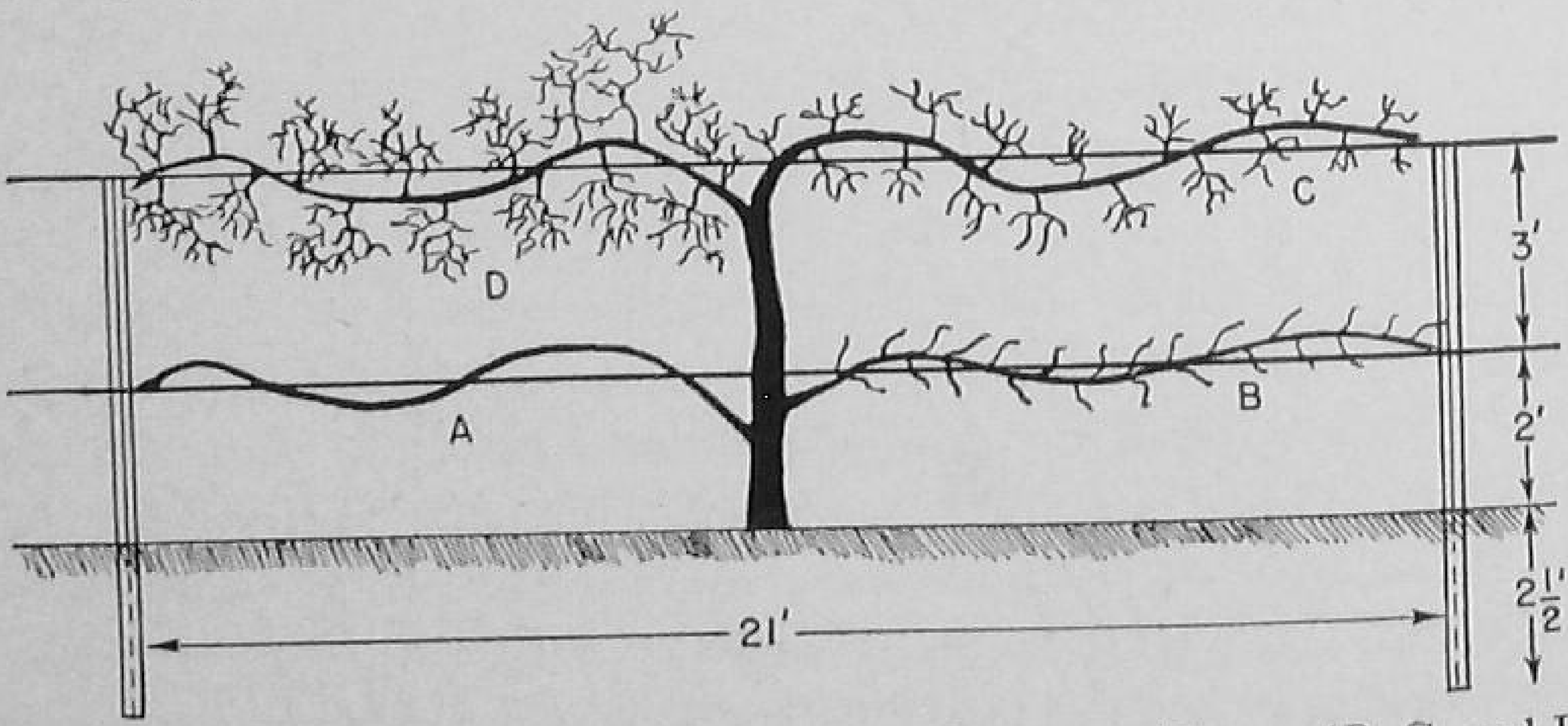


FIG. 82. Pruning the Muscadine grape. (A) One-year-old arm. (B, C, and D) Two-, three-, and four-year arms with fruiting branches. (Courtesy, M. Aubrey Owen, Gay, Georgia.)

The Brambleberries

(Black, Purple, and Red Raspberry, Blackberry, and Dewberry)

Fruiting Habit. Like the grape, the fruit of the brambleberries develop from mixed buds borne on one-year-old canes. The canes develop the first season, fruit, and then die the second season (except Himalaya blackberries in California). Pruning of the canes before they have fruited depends on the variety and method of training.

Black and Purple Raspberry. The black and purple raspberry usually set more fruit than the canes can adequately develop, hence they are pruned heavily. The kind and amount of pruning depends on the training system. In case the canes are grown with support the tips of the young shoots of the black varieties are "pinched off" when they are 12 inches high if grown in California, and from 18 to 24 inches high if grown in the Northeast and South. The tips of the purple varieties are "pinched off" when they are from 30 to 36 inches high. The "pinching off" induces the development of lateral branches and prevents the canes from becoming top-heavy. Just before growth starts in the spring the laterals are headed-back. The student should bear in mind that the fruit is borne on branches developed from the laterals. Investigations have shown that the number and size of the fruit can be regulated by the number of buds left. In general, if the canes are small two buds per lateral are sufficient. If they are vigorous from eight to ten buds per lateral can be left (see Figure 83).

Red Raspberry. The red raspberry produces tall erect stems. Pruning, other than removing the canes which have fruited, consists of thinning-out small or extra canes. In the Pacific Northwest excess canes are removed in the spring and the remaining canes are cut back in the winter. A Y-trellis is used to support the canes. In the central and eastern states the plants are pruned according to the method of planting. Under the hill

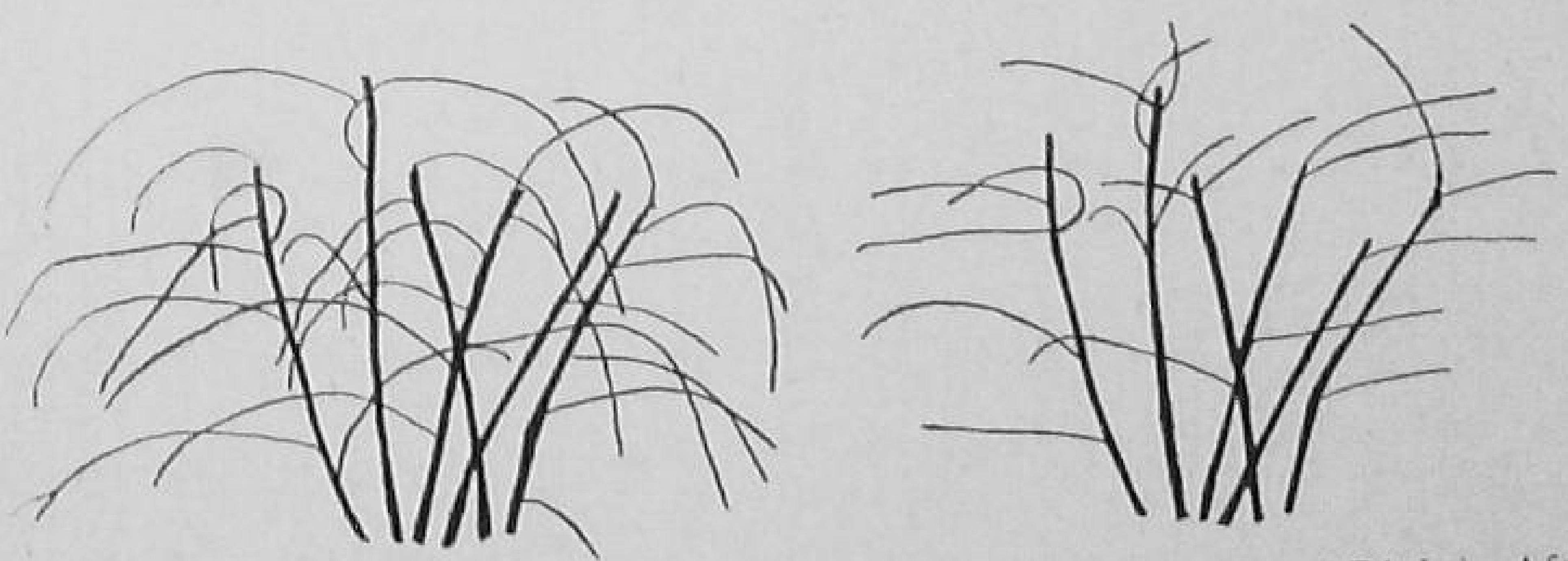


Fig. 83. Pruning the black raspberry. (*Left*) Before pruning. (*Right*) After pruning. (Redrawn from Fig. 10, *Kan. Agr. Exp. Sta. Cir. 239*, 1947.)

system the plants are set 5 feet apart each way, and pruning consists of removing all but about seven of the most vigorous canes per plant. Under the hedge system the plants form a solid row from 1 to 3 feet wide, and pruning consists of removing the small canes and leaving from three to four vigorous canes per linear foot of row (see Figure 84).

Blackberry. The blackberry is of two types: (1) Erect and (2) trailing. The erect varieties produce suckers like the red raspberry and are pruned and trained in much the same manner. In general, the plants are thinned from five to seven canes per hill in hill culture and from two to three canes per linear foot of row in hedge culture. The tips of the young canes may be "pinched off" when they are from 24 to 30 inches high. The pruning of the laterals is done in the winter. The amount of wood removed depends on the fruiting habit of the variety. Investigations have shown that some varieties produce most of their mixed buds at the base of the laterals and others produce most of them at the tips. In the former case the laterals are pruned to leave three or four buds; with the latter only the tips of the laterals are removed. The trailing varieties are trained to stakes or on horizontal or vertical trellises. Pruning, other than cutting out canes which have fruited, consists of reducing the number of canes per plant to facilitate the development of berries of large size and the production of vigorous canes for the following year.

Dewberry. The dewberry is trained on trellises, on stakes, or is allowed

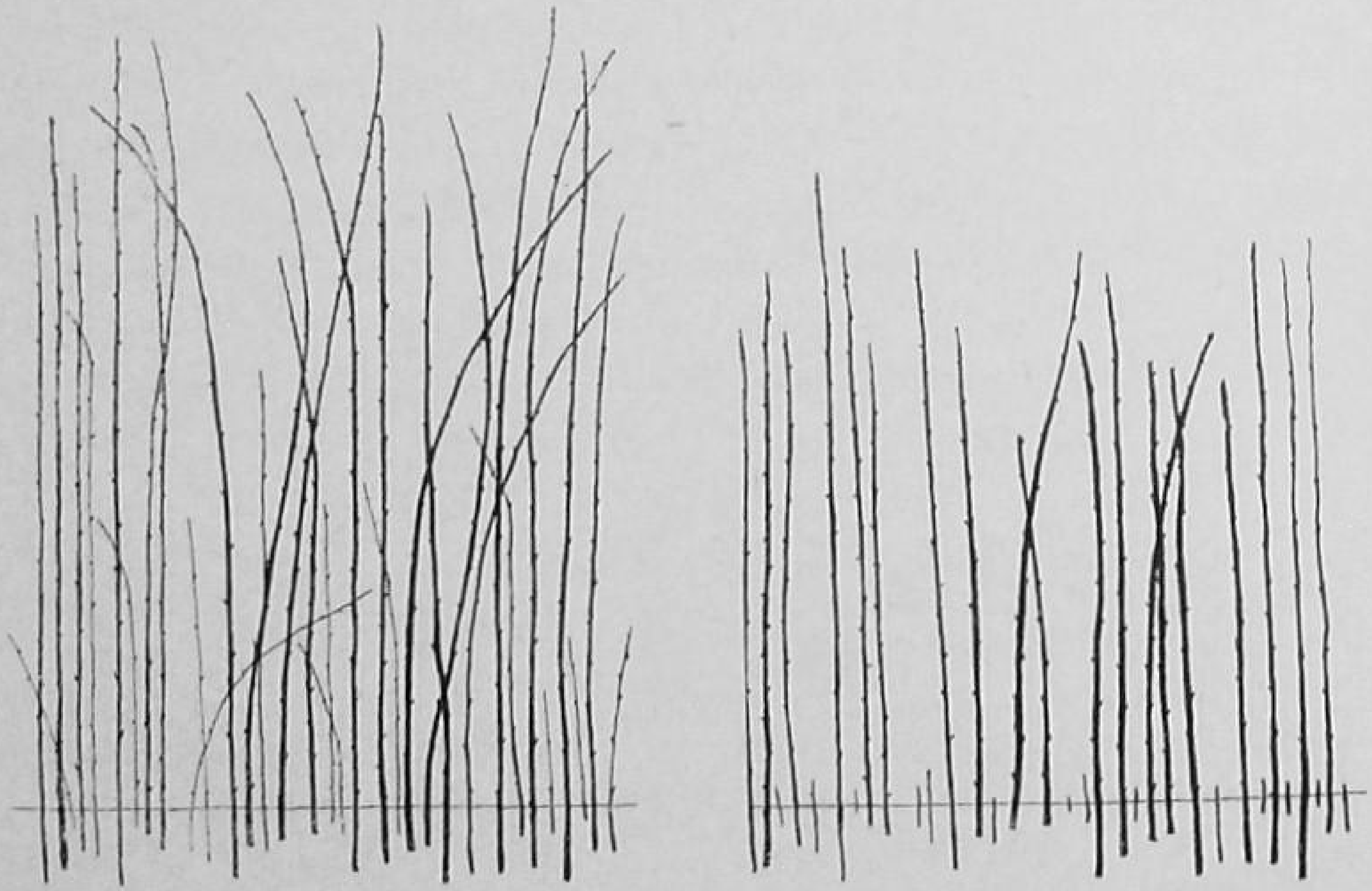


FIG. 84. Pruning the red raspberry. (*Left*) Before pruning. (*Right*) After pruning.

to grow on the surface of the land. All canes, both young and old, are removed after the harvest, and the canes which develop later are used for the next year's crop. These canes are tied to stakes the following spring or are allowed to run along the surface of the land.

Other Small Fruits

Blueberry. Like other small fruits, the blueberry produces fruit on one-year-old wood. Two important considerations are kept in mind in pruning: (1) Without pruning most varieties tend to overbear and produce small fruit and (2) the largest fruit is produced on the most vigorous wood. Consequently, the purpose of pruning is to induce the development of vigorous new wood and to reduce the number of flower buds. This is accomplished by removing weak, slender, and small branches throughout the body of the plant and by cutting back the fruiting branches. The amount of heading-back varies with the variety and growing conditions. Rancocus, Concord, and Rubel varieties require little heading-back; while Cabot, Pioneer, and others require cutting back to about three to six buds per shoot. Usually, little pruning is necessary for the first two years, only the weak slender wood is removed.

Currant and Gooseberry. The currant and gooseberry form many stems. With no pruning the plants become dense and unproductive. Since the fruit is borne on one-year-old branches, and on one-year-old spurs on two- and three-year-old branches, and very rarely on one-year-old spurs on older branches, pruning consists largely of removing branches over three years old. Enough one-year-old branches are left to replace those removed. Usually from eight to ten branches, well distributed throughout the plants, produce the highest yields. The branches seldom need heading-back.

Questions

1. Pruning of a tree or plant reduces its top and root growth. Explain.
2. Given two limbs growing from a common point and having equal size and vigor. Limb A is pruned back severely; limb B is left unpruned. Which will become the dominant limb? Give reasons.
3. Given two lots of tomatoes. Lot A is pruned to a single stem and topped at the sixth cluster; lot B is allowed to grow in the natural way. For a harvesting season of 6 weeks which lot produced the greater total yield? Explain.
4. Show how pruning the top increases the supply of water and nutrients to the remainder of the growing points.

5. Pruning the top promotes vegetative processes and retards reproductive processes. Explain.
6. How does thinning-out differ from heading-back? Give an advantage and a disadvantage of each.
7. Name the tree forms to which fruit trees are trained.
8. Severe pruning of the top delays flower bud formation in young deciduous fruit trees. Explain.
9. How is the thin wood method of pruning applied to mature bearing apple trees?
10. The modified leader type of peach tree produces stronger crotches and a more substantial frame than the open center type. Explain.
11. Show the relation of vigor of the tree and number of flower buds formed and yield of peaches.
12. How does the pruning of bearing peach trees differ from that of bearing apple trees?
13. How does the pruning of bearing peach trees differ from that of bearing plum trees?
14. Describe the fruiting habits of grapes and of the brambleberries.
15. What is the relation of vigor of grape canes to fruitfulness?
16. How does the single trunk, four-cane kniffin system of training differ from that of the fan system?
17. How does pruning the brambles differ from pruning bearing apple trees?
18. How does pruning of blackberries and black raspberries differ from that of red raspberries?

Assignment 20

Nut Fruits (Pecans, Walnuts, and Hazelnuts)

Fruiting Habit. The pecan, walnut, and hazelnut are monoecious. The pistillate flowers are borne, usually in clusters, on the current season's growth and arise from terminal mixed buds. The staminate flowers are borne in catkins and arise from the base of the leaves on the second season's wood. The individual flowers of both sexes are inconspicuous, and the pistillate flowers are wind-pollinated. Because the pistillate flowers and thus the fruit are borne on terminal branches, except when the crop should be thinned and the trees invigorated, severe heading-back would seriously reduce the production of nuts. Consequently, the pruning of vigorous bear-

ing trees consists largely of removing interfering, broken, dead, or diseased branches.

Pecans and hazelnuts are trained to the central leader type of tree, and walnuts are trained to the modified leader. In this way, higher branches will not excessively shade and thus retard the growth of the lower branches.

Citrus Fruits (Orange, Lemon, and Grapefruit)

Fruiting Period. Like other plants, citrus trees in any one year may produce: (1) Excessive stem and leaf growth and little fruit, (2) little stem and leaf growth and abundant fruit, and (3) moderate stem and leaf growth and moderately abundant fruit. Obviously, the moderately vegetative and the moderately productive condition is the most desirable. Hence, the problem in pruning citrus trees is to maintain a balance between stem and leaf growth on the one hand and the flower and fruit production on the other. Since the fruiting wood declines in productivity after the second and third year, the proper balance is maintained by the production of a moderate amount of new wood at a uniform rate each year. How is this objective obtained? Experience with citrus trees shows that they need not be pruned heavily every year but just enough to keep the tree growing fairly vigorously. The removal of conflicting, dead and broken branches as well as suckers each year is usually necessary. In addition it may be advisable to thin-out some of the old wood in order to stimulate the growth of new wood.

Figs

Figs produce two crops of fruit each year. The first crop or brebas is borne near the end of the previous season's wood and the second crop is borne in the axils of the leaves of the current season's wood. A number of weeks elapse between the ripening of the last fruit of the first crop and the ripening of the first fruit of the second crop.

The type of pruning required depends on the crop grown. For varieties which are grown primarily for the first crop or for both crops, the thinning-out of the dead, broken, or diseased branches is all that is necessary. For varieties which are grown mainly for the second crop, such as Kadota group in California, heading-back rather severely is required in order to keep the trees low and thus make picking less expensive.

Ornamental Trees, Shrubs, and Vines

Ornamental Trees. Two general types of pruning are required for ornamental trees: (1) The removing of dead, diseased, or injured branches

and (2) the keeping of trees of the foundation planting within due proportion of the dimensions of the house. Evergreen trees such as the junipers and arbor vitae must be pruned regularly to keep them within due bounds. Spruces, pines, and similar evergreens seldom require pruning.

Ornamental Shrubs. The growth and flowering habits of ornamental shrubs and those of the small fruits are quite similar. The stems produce flowers for 1, 2, or 3 years and die. Consequently, the pruning requirements of shrubs grown for their flowers and foliage and of shrubs grown for their fruit are essentially the same. Pruning, therefore, consists of the removal of dead and weak stems. These stems are cut at the surface of the land; hence, pruning of ornamental shrubs is a thinning-out process.

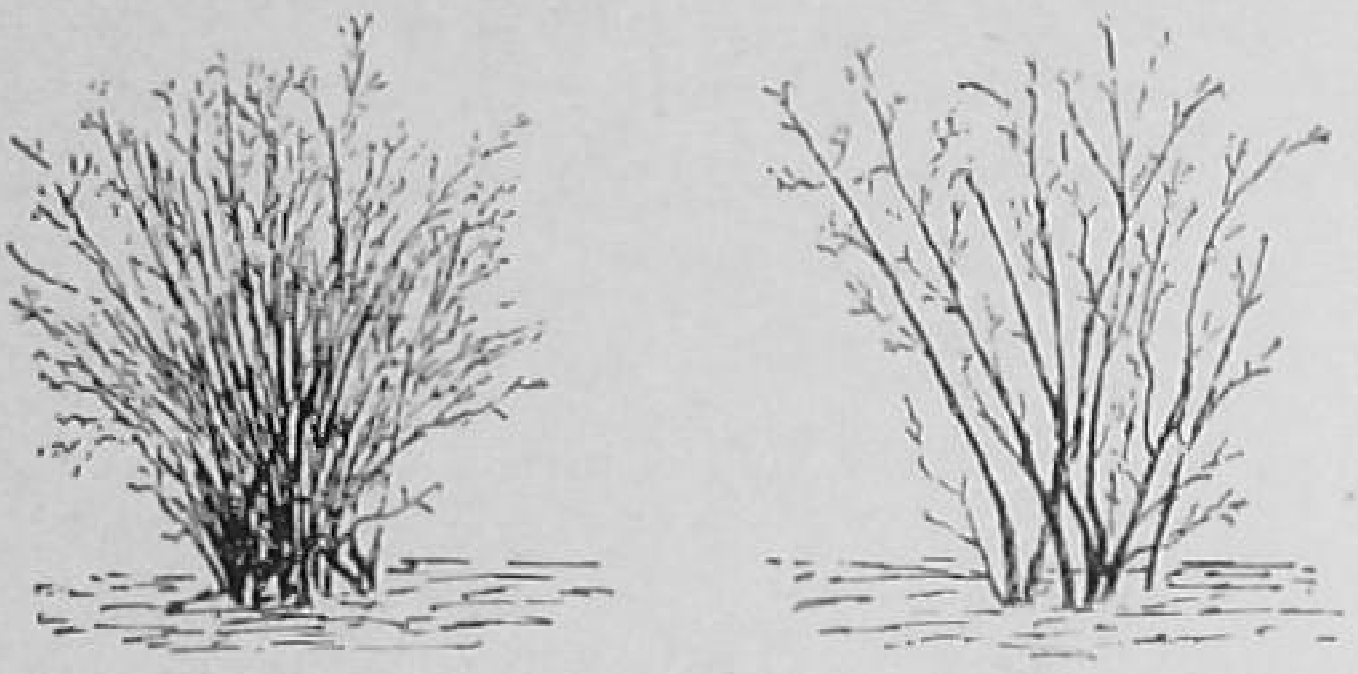


FIG. 85. Pruning flowering shrubs. (*Left*) Before pruning. (*Right*) After pruning. (Redrawn from Batson, F. S. and Monosmith, R. O.: Care of ornamental trees and shrubs, *Miss. Agr. Exp. Sta. Bul. 354,* 1941.)

The time of the year for pruning shrubs depends on the age of the wood which produces the flowers. According to the Michigan Experiment Station most shrubs can be classified as follows: (1) Shrubs which are pruned before they blossom and (2) shrubs which are pruned immediately after they blossom. In the first case all shoots more than 1 year old are removed and the remainder are thinned depending on the vigor of the plant. Examples are: Hills of Snow hydrangea, Anthony Waterer spirea, and Froebels spirea. In the second case all the dead, non-flowering stems are removed and the remainder are thinned according to the vigor of the plant. Examples are: spireas, honeysuckles, Flowering Almond, and lilacs. Shrubs which require little, if any, pruning for a long period of years are forsythias, viburnums, Shrubalthea, and redbuds (see Figure 85).

Woody Vines. Woody vines such as English Ivy, Virginia Creeper, and the bittersweets usually require little pruning. In general, only dead or injured branches are removed. However, some vines, bittersweet and grape,

when comparatively old, produce laterals from the upper stems only, thus leaving the base without foliage. To correct this situation the older stems are headed-back to the ground. As a result the top is renewed from the younger shoots.

Roses

The kind and severity of pruning of the rose depends on the kind of rose grown and the size of flower desired. Some kinds require severe annual pruning and other kinds require little or no pruning. Roses which require

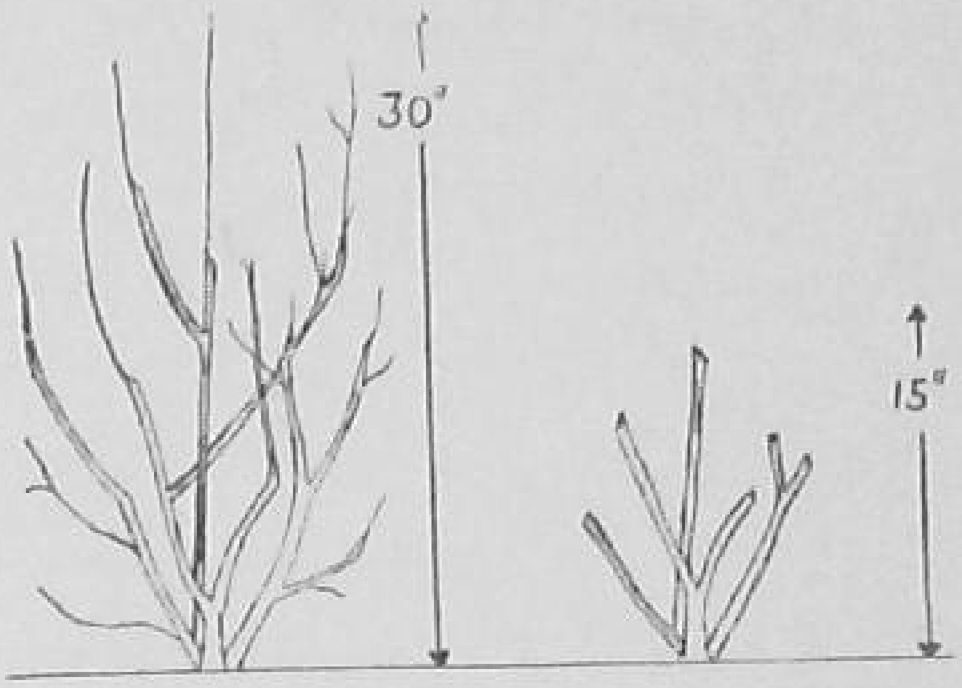


FIG. 86. Pruning the hybrid tea rose. (*Left*) Before pruning. (*Right*) After pruning. The degree of heading-back depends on the number of flowering stems desired and on the variety. (Redrawn from Batson, F. S. and Monosmith, R. O.: Care of ornamental trees and shrubs, *Miss. Agr. Exp. Sta. Bul. 354*, 1941.)

severe pruning are the hybrid perpetuals and the hybrid teas. These kinds are grown for cut flowers. In general, the weak stems are thinned-out and the sturdy stems are headed-back to varying heights depending on their vigor. In heading-back all cuts are made to an outer bud to promote spreading of the plant. From six to ten buds are usually left on each stem. The student should remember that cutting of flower stems is essentially a pruning operation. Usually, flower stems are cut so as to leave one to three nodes of the current season's growth on the stem (see Figure 86).

Roses that require relatively little pruning are the climbing, rambler, and rugosa types. Climbers are pruned immediately after they have finished flowering. Stems which produce flowers are removed to facilitate the development of new shoots. These new shoots produce flowers the following year. Ramblers require a small amount of heading-back and removal of

dead and weak wood. Rugosa types require the removal of old, weak, dead, or diseased wood only.

Hedges

Ideal hedges make uniform growth within any season and are dense from base to top. To accomplish uniformity of growth the plants must be subjected to a uniform environment, particularly a uniform water supply, nutrient supply, and light supply. This is especially true of the light supply. Clearly, with other environmental factors in favorable supply, that part of the hedge growing in shade will make less growth than that part growing in sun. To secure density and a compact type of growth from base to top, the frequent formation of lateral shoots throughout the life of the hedge is necessary. Thus, the heading-back type of pruning is used. In general, the plants are headed-back to a uniform height when they are set. As the new shoots attain a length of from 6 to 12 inches they are headed-back to a length of from 3 to 6 inches. This practice is continued until a desired height is reached, after which a severe heading-back is practiced. Naturally the number of trimmings in any one season depends on the amount of growth made. Heading-back induces the development of lateral buds on the older wood, and as a result the body of the hedge is as dense as the top. Figure 87 shows satisfactory and unsatisfactory shapes for hedges.

PRUNING TOOLS FOR WOODY PLANTS

For the pruning of woody plants three kinds of tools are essential: (1) Hand pruning shears for small cuts up to ½ inch in diameter, (2) lopping shears with 24- to 30-inch handles for cuts between ½ and 1 inch in diameter, and (3) pruning saws for larger cuts. All pruning tools should be sharp in order to make clean non-jagged wounds.

Time of Pruning Woody Plants. Woody plants are generally pruned between the time of leaf-fall and blossoming. Recent investigations have

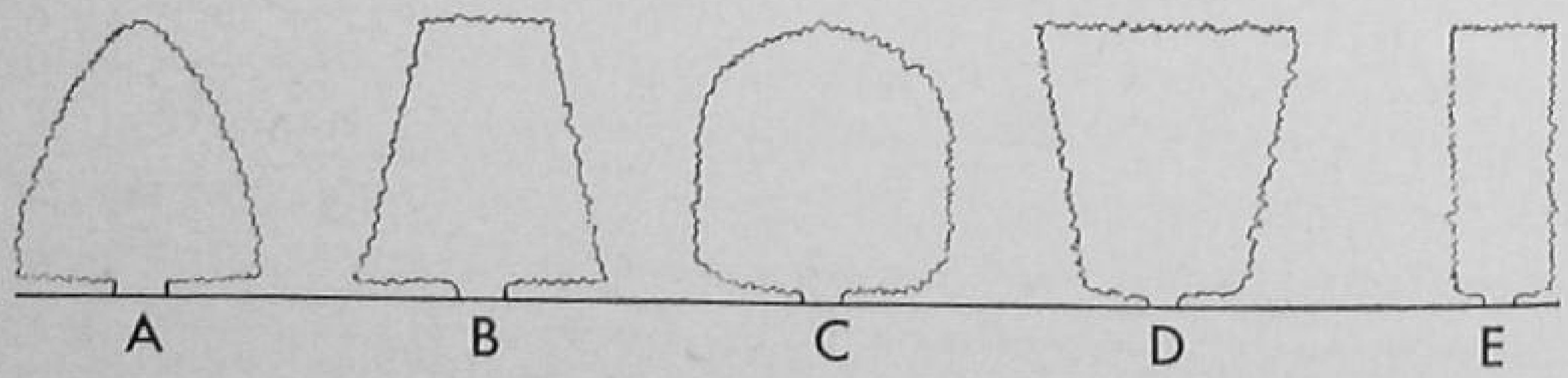


FIG. 87. Pruning the hedge. Satisfactory and unsatisfactory shapes. (A–B) Good. (C) Fair. (D–E) Poor.

shown that pruning wounds made in early spring heal more quickly and effectively than those made at any other time of year. At this time the wound cork cambium forms readily and produces a layer of corky tissue rather quickly. Furthermore, the temperatures of the spring are more favorable for the activity of the wound cork cambium than those of the winter.

How Are the Cuts Made? Cuts involving the removal of entire shoots, twigs, and branches are made flush with the adjoining branch or limb. In other words there is no stub or projecting end of the cut branch. Observation shows that cut surfaces of stubs heal less rapidly than the cut surfaces of wounds close to the branch or limb. In fact, unless a shoot forms at the cut end, the surface of the stub rarely heals. Thus, pruning wounds will heal more rapidly if they are made close to the base of removed branches or limbs and parallel to the part from which it was taken.

Treatment of Pruning Wounds. Many preparations are available for coating the surface of pruning wounds on woody plants. An ideal preparation should: (1) Facilitate the development of callous tissue and (2) prevent the invasion of rot-producing organisms. There is no preparation that fully meets these requirements. Some contain disinfectants that retard the rate of callous formation; others retard or entirely prevent the flow of air into the wound; and others crack and thus allow rot-producing organisms to invade the tissue.

Pruning the Stem of Herbaceous Crops

Important herbaceous plants which are pruned are tomatoes in greenhouses, tomatoes outdoors, cucumbers in greenhouses, chrysanthemum, dahlia, zinnia, calendula, and mignonette.

Tomatoes in Greenhouses. Tomatoes grown in greenhouses are always trained and pruned. Individual plants are usually trained to a single stem which is supported by a stake or string. The laterals are pinched off as soon as they arise in the axils of the leaves, thus the thinning-out type of pruning is employed. Pruning in the greenhouse permits close setting, development of fruit above the soil, and facilitates spraying of the plants and picking of the fruit. Since the water and nutrient supply are under the control of the grower, competition between plants, particularly for water and nutrients, is reduced to a minimum and comparatively large yields per unit area are secured.

Tomatoes Outdoors. Tomatoes are pruned in certain commercial sections for the fresh market and in many home gardens. The plants are trained to one, two, or three stems and are topped at the fourth, fifth,

sixth, or succeeding flower cluster. Stakes are usually used for support. The effect of pruning and training tomato plants outdoors on the production of fruit has been investigated by many experiment stations. Advantages and disadvantages of the practice as set forth in *New York (Cornell) Experiment Station Bul. 580,* 1934, follow:

Advantages	*Disadvantages*
1. Permits close spacing of plants	1. Increases cost of production
2. Increases early yield of fruit per acre	2. Requires stakes and twine for training plants
3. Keeps fruit off the ground	3. Requires labor for setting the stakes and pruning and tying the plants
4. Facilitates spraying of plants and harvesting of fruit	4. Requires labor for removing and storing stakes

Cucumbers in Greenhouses. Like tomatoes, cucumbers grown in greenhouses are always trained and pruned. Individual plants are trained to a single stem and are usually supported by string fastened to a single wire trellis from 4 to 8 feet above the level of the land. For about 2 months after the plants are set, the primary laterals are cut back to the first or second female blossom, and the secondary laterals are "pinched out." Thus, both heading-back and thinning-out are used. As in the case with tomatoes, the pruning and training of cucumbers in greenhouses permits close setting of the plants and the development of fruit above the ground.

Chrysanthemums. Chrysanthemums, particularly the large flowering or standard types, are given a special type of pruning called disbudding. Chrysanthemums produce two types of flower buds: (1) Crown buds and (2) terminal buds. Crown buds appear first and are surrounded by leaf buds, and terminal buds appear later and are surrounded by other flower buds. According to authorities at the Ohio Experiment Station, the use of crown or terminal bud depends largely on the variety. On early maturing varieties crown buds produce the most satisfactory type of flower, and on late maturing sorts terminal buds are the more satisfactory. In either case, only one flower is allowed to develop on each plant. In this way a large inflorescence is obtained. Other flower crops which are disbudded are camellia and zinnia. The disbudding of camellia is illustrated in Figure 88.

The stems of many flowering plants are headed-back or "pinched" to produce the development of a large number of stems and flowers per plant. Examples of plants headed-back in this way are the pompon varieties of chrysanthemum, calendula, and mignonette.

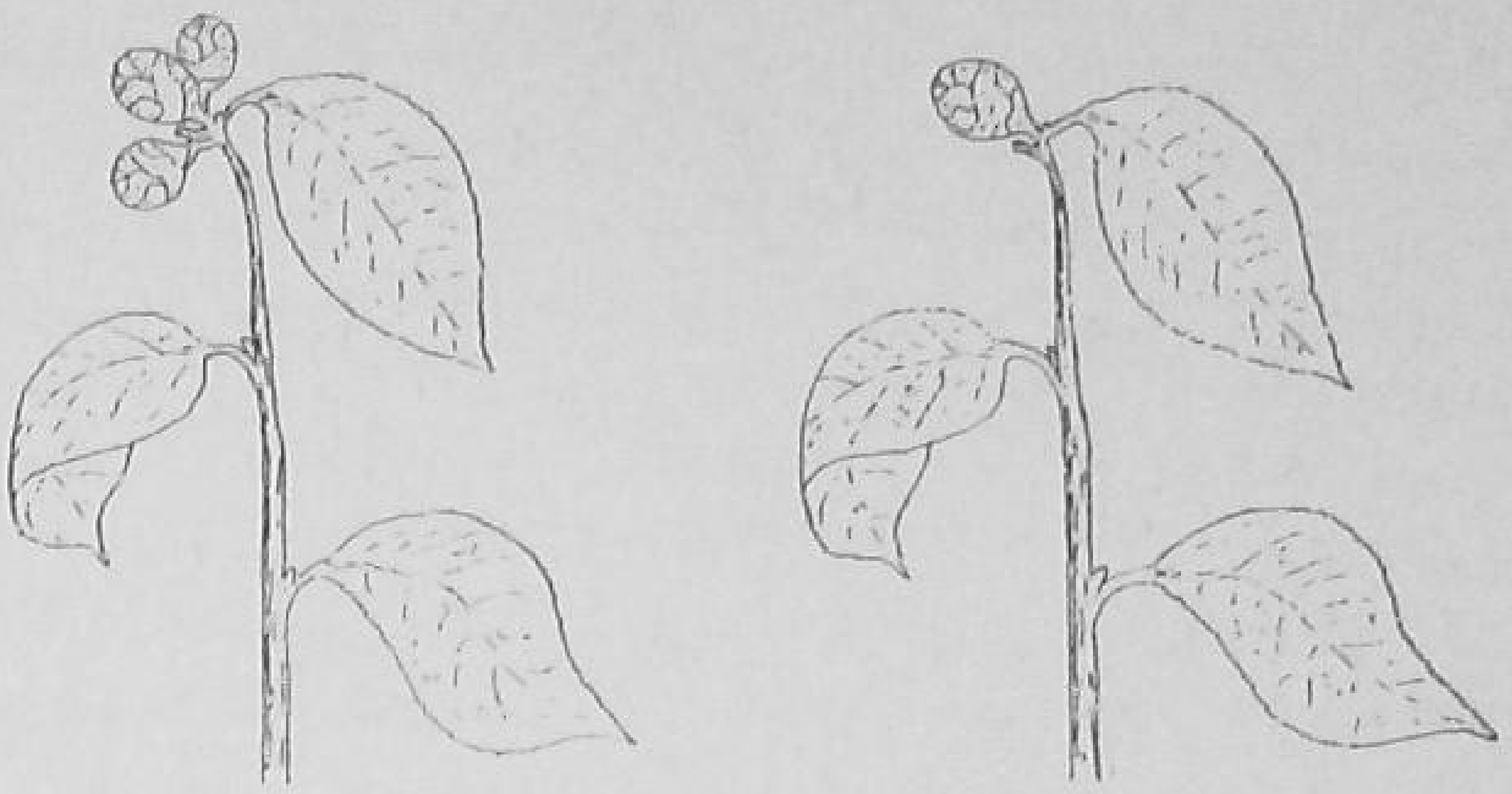


FIG. 88. Disbudding of camellia. (*Left*) Before. (*Right*) After.

PRUNING THE ROOT

Root-pruning consists of the removal of part of the root system of plants. Root-pruning like top-pruning affects the total amount of growth made and the vegetative-reproductive balance.

Total Amount of Growth Made. Investigations have shown that root-pruning dwarfs the tree or plant in much the same way, although not in the same degree, as top-pruning. Root-pruning removes certain portions of the root system. The roots require carbohydrates for growth and primary and secondary roots of woody plants store carbohydrates also. Thus, root-pruning partially invalidates carbohydrates which have been used for the growth and maintenance of the roots, and wholly invalidates those which have been stored in the removed roots. In other words, to replace the removed roots the plants develop other roots. These new roots require carbohydrates which could otherwise be used for other purposes.

Vegetative-reproductive Balance. Root-pruning influences growth and development through its effect on the water supply and the nutrient supply, it will decrease the rate of cell division and enlargement. Thus, root-removal of the root system correspondingly reduces the area for water absorption. This in turn reduces the amount of water that can be absorbed. Since abundant water within the plant is necessary for a rapid rate of cell division and enlargement, and since root-pruning decreases the water supply, it will decrease the rate of cell division and enlargement. Thus, root-pruning retards vegetative processes and, as a result, favors reproductive processes. How does root-pruning affect the nutrient supply? Naturally, root-pruning decreases the number of root hairs. This in turn decreases the amount of nutrients absorbed. This is turn decreases the rate of cell division and enlargement, and reduces the utilization of carbohydrates and

thus favors accumulation. In other words, root-pruning favors reproductive processes more than vegetative processes. The student will note that root-pruning has the same effect of top-pruning on the amount of growth that can be made and the opposite effect of top-pruning on the vegetative-reproductive balance.

Pruning the Root of Woody Plants

Up to the end of the nineteenth century root-pruning was practiced and recommended in Europe, particularly in England, for the culture of fruit trees. In England fruit trees were grown mostly on dwarf stock. A circular trench usually about 18 inches from the base of young trees and about 18 inches deep was made around the tree and all exposed roots were cut with a sharp knife. For each succeeding year the distance of the trench from the base of the tree was slightly increased so that the roots of any one year were pruned from 2 to 3 inches from the stubs of the previous year. It was generally recommended that the trenching be done in the fall. In this way the trees would show a reduced vegetative growth the following spring and an increase in flower bud formation in the summer. The student should remember that heavy manuring was practiced also. In fact, the growers generally filled the trench with manure or compost. Since these materials stimulated vegetative growth and since root-pruning, as briefly described, reduced vegetative growth, the one practice had a nullifying effect on the other. Studies in American orchards during the early part of the twentieth century showed that root-pruning markedly reduced the life and the yield of fruit trees. In this country orchards are not heavily manured, and lack of vigor is a more serious problem than excessive vigor. Consequently, root-pruning by trenching is no longer recommended and practiced.

Pruning the Root of Herbaceous Crops

Certain vegetable plants, particularly tomatoes and cabbage, when grown in flats are blocked about a week or 10 days before they are set out in the field. Blocking consists of running a sharp knife or a hoe, with a straightened shank, down the middle of the rows in both directions. This operation cuts the root system of the plants, reduces water and nutrient absorption and thus reduces vegetive extension and permits carbohydrate accumulation. These carbohydrates are used for the development of a new root system within the blocked soil. Thus, blocking is essentially a root-pruning practice.

Questions

1. How does the pruning of mature citrus trees differ from that of the peach trees?
2. Heavy heading-back of pecan branches would greatly reduce the yield. Explain.
3. The heading-back of figs grown for the first crop of fruit would seriously decrease the yield. Explain.
4. The pruning requirements of ornamental shrubs are similar to those of the brambleberries. Explain.
5. Show how heading-back of a large spirea bush would destroy its esthetic and ornamental value.
6. How is density secured in the development of a privet hedge?
7. How does the pruning of hybrid tea roses differ from that of rambler roses?
8. How do woody plants heal their cut surfaces?
9. Pruning wounds made in the early spring just before growth starts heal more quickly than those made in the winter. Explain.
10. Cuts made at the base of removed branches or parallel to the branch from which it was removed heal more effectively than cuts made away from the base. Explain.
11. State the two main requirements of preparations for the treating of wounds. Give reasons.
12. How are chrysanthemums disbudded? What is the object of disbudding?
13. The pruning of tomatoes and cucumbers in greenhouse culture is a necessary practice for profitable production. Explain.
14. State two advantages and two disadvantages of pruning and training tomatoes grown outdoors.
15. How does root-pruning reduce the total amount of growth made?
16. The root-pruning of orchard trees as a practice is injurious. Explain.

14

Control of Pests

Assignment 21

Only living things that contain chlorophyll make foods—the carbohydrates, proteins, and fats and related compounds. Conversely, all living things that are without chlorophyll cannot make food. These organisms that are without chlorophyll use the food made by green plants. Thus, they are dependent on green plants for their existence. The three great groups of dependent organisms are: (1) Animals, including man, (2) fungi, and (3) bacteria.

The various groups of dependent organisms use the products of photosynthesis for their growth and development. Many organisms within each group are continuously competing with man for these products. For example, man is constantly fighting certain insects which reduce plant yields and certain plants which cause disease. Since these organisms compete with man for the products of photosynthesis they are called pests. This competition is so great that man has organized groups (entomologists, nematologists, and plant pathologists) to study the life cycle and habits of pests. He has developed many materials and many devices for their control. Growers of horticultural plants, like the growers of other crops, must devote a great deal of their time and energy to combat pests in order to obtain profitable crops. These pests are classified as follows: (1) Those belonging to the animal kingdom and (2) those belonging to the plant kingdom.

PESTS BELONGING TO THE ANIMAL KINGDOM

Pests belonging to the animal kingdom are many kinds of insects, certain kinds of mites, many kinds of nematodes, and a miscellaneous group.

Insects

Insects have three pairs of legs and three body regions. They may be classified according to the way they feed on plants. In general, there are two groups: (1) Those with biting mouth parts and (2) those with sucking and/or rasping mouth parts.*

Insects with Biting Mouth Parts. Insects with biting mouth parts are classified according to the part of the plant on which they feed. In general, there are four more or less distinct groups: (1) Those that feed on leaves and/or stems, (2) those that feed on roots, (3) those that bore into stems, and (4) those that feed on fruits, seed, or fleshy storage structures.

Stem and Leaf Eaters. These are voracious feeders; thus they reduce the photosynthetic area very quickly. They may be placed in four groups: (1) Caterpillars, (2) beetles and their larvae, (3) grasshoppers, and (4) leaf miners. *Caterpillars* are the larvae of butterflies and moths. Examples are: the cabbage worm, tomato or tobacco worm, celery worm, cutworm, and apple tree tent caterpillar. *Beetles and their larvae* may be placed in two groups: general feeders; for example, Japanese beetle and blister beetle and specific feeders; those that feed on one crop or related group of crops. In general, specific feeders usually are named for the crop to which they do the most damage. Examples are: asparagus beetle, common bean beetle, Mexican bean beetle, Colorado potato beetle, cucumber beetle, and rose chafer. *Grasshoppers* are general feeders. The young nymphs and adults eat large quantities of non-woody tissue. Since the eggs are laid in sod, grasshoppers are usually more numerous in cultivated crops next to sod land than otherwise. *Leaf miners* as a group are relatively few in number. The larvae eat the tissues between the epidermis in the leaves. Examples are: spinach leaf miner, rose leaf slug, and arbor vitae leaf miner.

Root Feeders. Root feeders usually eat the younger portions of the root system. They naturally reduce water and nutrient absorption. As previously stated, a mild reduction will reduce the rate of cell division and cell enlargement and promote carbohydrate accumulation, and a severe reduction will result in wilting and low yields. Examples of root feeders are:

*A convenient term meaning one or the other or both.

larvae of the cucumber beetle and the white fringe beetle, strawberry root worm, and white grubs—the larvae of the May or June beetle.

STEM BORERS. Stem borers are caterpillars of moths or larvae of beetles. They tunnel within the root and stem systems. They may be placed in two groups: (1) Herbaceous stem borers and (2) woody stem borers. Herbaceous stem borers eat practically all of the internal tissues while woody stem borers eat only relatively small portions. Unlike surface feeders, stem borers often do extensive damage before their presence is known. Examples of herbaceous stem borers are: the squash vine borer, pickle worm, cabbage and onion maggot, and European corn borer. Examples of woody stem borers are: peach tree borer, apple tree borer, and raspberry cane borer.

FEEDERS ON FLESHY FRUITS, SEED, AND STORAGE STRUCTURES. These are usually the larvae of moths and beetles. These larvae eat large quantities of food and make the products unfit for human consumption. In a sense these insects have successfully competed with man for their food. Examples are: cotton boll weevil, bean weevil, pea weevil, tomato fruit

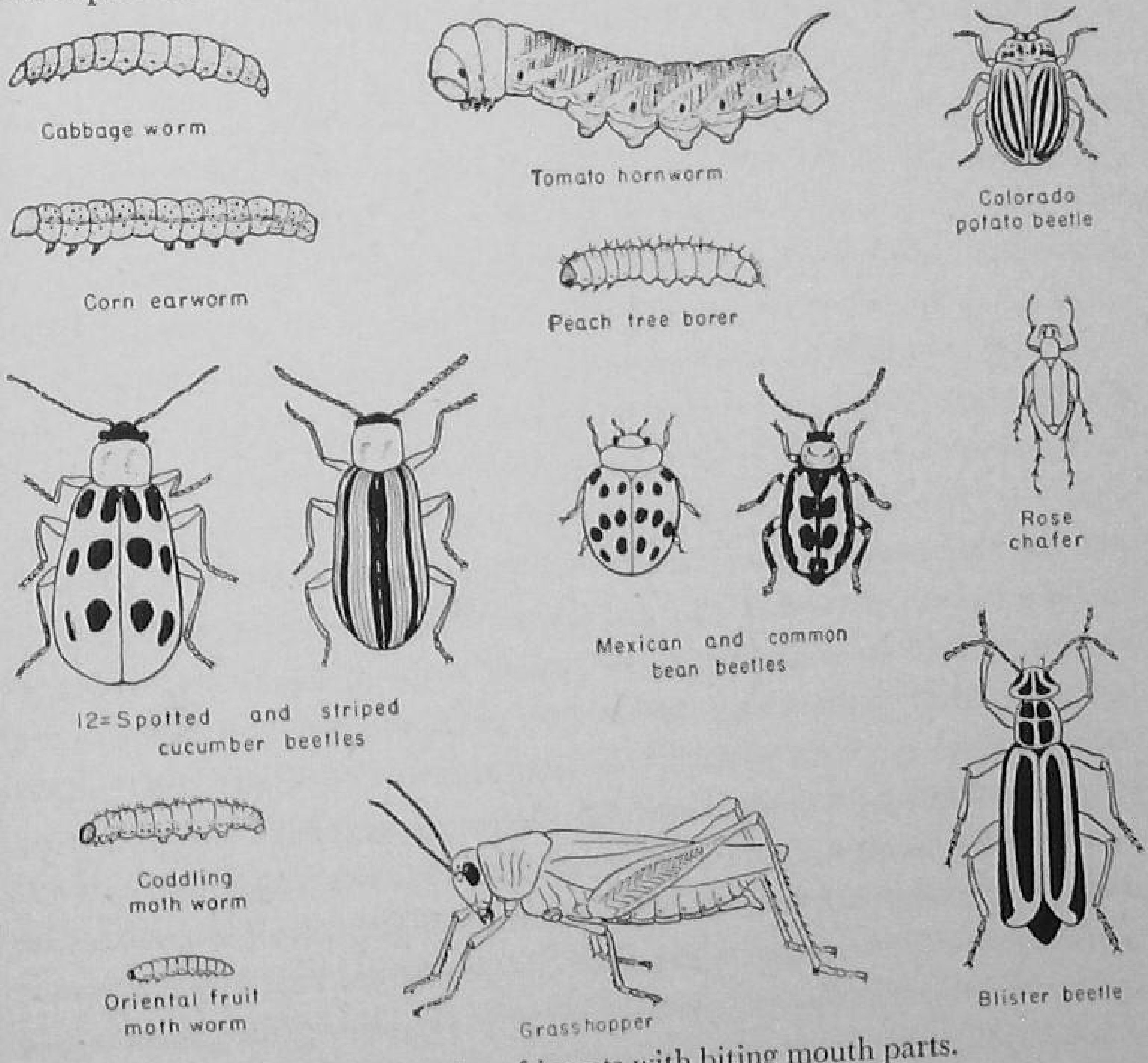


FIG. 89. Examples of insects with biting mouth parts.

worm, corn ear worm, plum curculio, Oriental fruit moth worm, and sweetpotato weevil. Some of the more common insects with biting mouth parts are shown in Figure 89.

Insects with Sucking or Rasping Mouth Parts. Principal sucking or rasping insects are aphids, bugs, thrips, leafhoppers, and scales and mealy bugs. *Aphids* are small, soft-bodied, pear-shaped, sometimes winged and sometimes not winged. They reproduce very rapidly, with 5 to 15 generations per growing season, usually prefer the lower surface of the leaves and comprise many genera and species. They are particularly troublesome on apples, beans, cotton, grapes, garden pea, potato, spinach, spirea, and

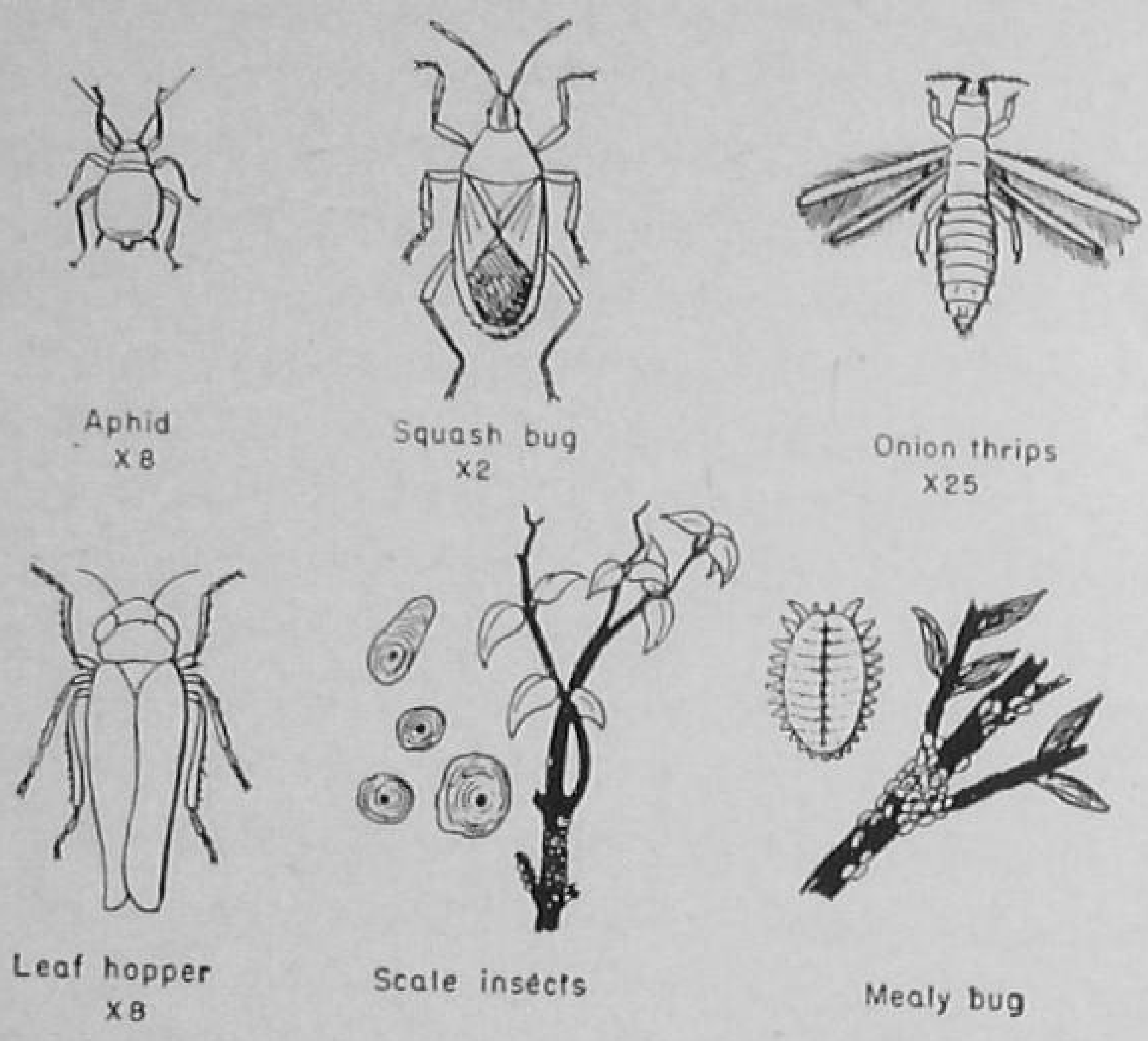


Fig. 90. Examples of insects with sucking mouth parts.

rose. *Bugs* are large with four wings which lie flat on the body. In general, they destroy chlorophyll, malform buds and fruit, and often induce permanent wilting. Examples are: the squash bug, the Harlequin cabbage bug, and tarnished plant bug. *Thrips* are extremely small and slender with rasping mouth parts. In general, they destroy chlorophyll and thus reduce the plant's capacity to make foods. Thrips are particularly troublesome on citrus, onion, gladiolus, and many ornamentals. *Leafhoppers* are moderately small, elongated, four-winged, which are held in the form of a roof while at rest. They comprise many kinds. The kinds that attack potatoes and asters are particularly important, since they carry certain viruses which seriously reduce the photosynthetic capacity of the crops. *Scales and mealy*

bugs are moderately large with the female considerably larger than the male. Their bodies are covered with scale-like secretions in the case of scales and waxy-like secretions in the case of mealy bugs. These secretions serve as protection and are quite resistant to chemical compounds. In general, scales are more troublesome on woody plants and mealy bugs are more troublesome on herbaceous plants. Examples are: oyster shell scale, San Jose scale, camellia scale, grape mealy bug, Mexican mealy bug, and Taxus mealy bug. Some of the more common insects with sucking mouth parts are shown in Figure 90.

Mites

Mites have four pairs of legs and two body regions. They comprise the spiders, scorpions, daddy longlegs, and ticks. Of these the most serious pests are the so-called red spiders and mites. There are many kinds and varieties. Some of the most common, widespread, and troublesome are: (1) Common red spider, (2) bulb mite, (3) cyclamen or strawberry crown mite, and (4) citrus mite. *Common red spiders* are microscopically small, vary in color—yellow, orange, or red, spin webs profusely on which they travel from leaf to leaf and from plant to plant, and reproduce rapidly, particularly in warm-dry greenhouses and outdoors where continuous breeding can take place. They pierce the foliage usually on the under side of the leaves with two prong-like projections, and cause the leaves to turn yellow at first and then brown. The common red spider attacks a large number of horticultural crops—chrysanthemum, carnation, cucumber, dahlia, hydrangea, onion, rose, snapdragon, strawberry, and tomato are examples. *Bulb mites* are colorless, slow moving, and usually exist in colonies. They feed on both healthy and rotted tissue, hence they spread disease rapidly. As the name suggests, bulbs and similar storage structures become infested—bulbs of lily and onion, corms of gladiolus and crocus, and rhizomes of asparagus and peony are examples. *Cyclamen or strawberry crown mites* are exceedingly small (they cannot be seen by the naked eye), slow moving, white or pale green. They attack many crops—ageratum, azalea, begonia, geranium, marigold—and are particularly injurious to cyclamen, snapdragon, and strawberry. In general, they destroy chlorophyll, pucker and curl the leaves, twist and gnarl the flowering stems, distort the blooms, and even prevent the development of flowers and fruit. *Citrus mites* are red or dark red and reproduce rapidly under warm-dry conditions. Thus, they are quite serious in the citrus-growing districts of California. In general, both the adults and nymphs

induce a grayish color to the leaves. Therefore, they destroy chlorophyll and reduce the rate of photosynthesis. The degree of infestation is inversely proportional to the marketable yield. Figure 91 shows the effect of red spider injury on the leaves of sweetpotato. Note the yellowish green areas.

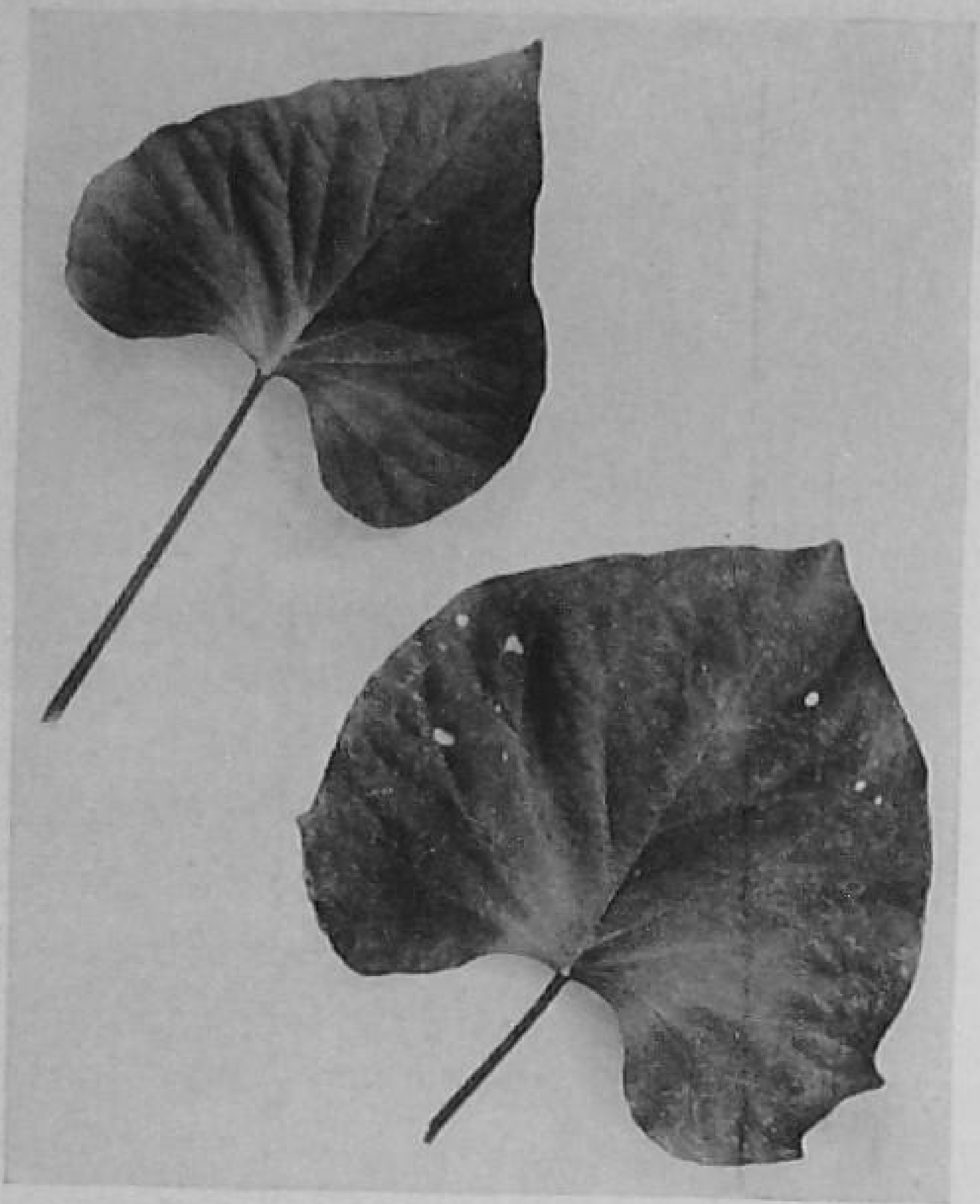


FIG. 91. Red spider injury on sweetpotato leaves. (*Upper*) Healthy leaf. (*Lower*) Moderately infested leaf. Note the yellow areas. (Courtesy, Ross E. Hutchins, Mississippi State College.)

NEMATODES

Nematodes are small eel-like worms which live in the soil and in plant tissue. They bore into the feeding roots of a large number of horticultural crops—peaches, tomatoes, cucumbers, cantaloupes, carrots, beets, and many others—and induce the development of knots or galls. These galls interfere with the absorbing system in such a way that the rate of water absorption is reduced. In general, the first symptom of nematode injury is wilting during the hotter portion of the day followed by permanent wilting and death. When wilting first occurs the roots of the plants are usually loaded with galls. The galls are comparatively large, round or elongated, and can be distinguished readily from nodules formed by nitrogen-fixing

FIG. 92. Nematodes on roots of squash. (*Left*) Healthy. (*Right*) Nematode infested. Note the formation of galls. (Courtesy, John T. Presley, Mississippi Agricultural Experiment Station.)

bacteria. Nematodes are particularly prevalent in the Southern regions where winter temperatures are comparatively mild. Most horticultural crops are susceptible. In fact, only few varieties are resistant. These belong to the following kinds: apricot, avocado, citrus, date, peach, plum, and snap bean. Note the formation of galls on the roots of squash in Figure 92.

Miscellaneous Group

The miscellaneous group includes rodents and certain birds. Rodents comprise ground moles, field mice, and rabbits. The *ground mole* frequently damages lawns and crops grown in the garden, and occasionally damages crops grown in the field. These animals, searching for white grubs and other insects in the soil, make tunnels and thus loosen the soil and seriously disturb the root system. *Field mice* are frequently troublesome during the planting season. They eat the seed; this often necessitates replanting. *Rabbits* frequently damage trees in the orchard. They eat the bark at the base of the tree.

PESTS BELONGING TO THE PLANT KINGDOM

Plant pests are minute plants and substances which act like plants. They have no chlorophyll, hence they cannot manufacture their own food.

They must live, as all animals must live, on the food that green plants have made. The student should remember that not all minute plants are harmful to green plants. Some are distinctly beneficial, such as the fungi which decompose organic matter, and the bacteria which change ammonia to nitrates.

Many plant pests live on horticultural crops. They attack the plant in various ways. Some attack crop plants in the seedling stage and thus reduce the stand; others attack the leaves and thus reduce the plant's capacity to make food; others attack the stem and disrupt the food, water, and nutrient transportation systems; and others attack the marketable product. In all instances profitable yields per plant or per unit area are decreased. Plant pests are classified as follows: (1) Fungi, (2) bacteria, and (3) viruses.

Fungi

Fungi consist of many cells. The body may be divided into two parts: (1) The fine thread-like strings of cells collectively called mycelia and (2) the spore cases called the fruiting bodies. The mycelia are the vegetative part and the spore cases are the reproductive part. Fungi can multiply and spread by fragments of the mycelia or by germination of the spores. Under favorable conditions each type of structure is capable of growing into a new individual. The fungi which attack horticultural crops constitute a large group. Their mode of living and manner of feeding on the host plant varies greatly. They are classified as follows: (1) Fungi with practically all of their mycelia and all of their fruiting bodies on the surface of the plant. (2) Fungi with all of their mycelia within the plant and spore cases that break through the outer cover. (3) Fungi with the entire body within the plant.

Fungi with practically all of their mycelia on the surface of the host plant are external feeders. An example is the powdery mildews. On infected plants the mycelia can be seen as fine welts of grayish threads among which are interspersed small brown or black fruiting bodies. The fungus attacks the lower side of the leaves more than the upper side and thrives best in warm-humid conditions.

Fungi with mycelia within the tissues of the plant and spore cases that break through the outer cover are in a sense the lesion producers. They may be divided into four groups: (1) Anthracnoses, (2) downy mildews, (3) leaf spots, and (4) rusts. In general, the lesions are small at first and water-soaked. They gradually enlarge and assume a characteristic color,

gray, brown, or black, depending on the color of the spore cases of the fungus. Frequently the fungus grows so rapidly that the spots grow together (coalesce). The lesion producers attack many horticultural crops. Examples are presented in Table 22 and in Figures 93 and 94.

Table 22

TYPES OF FUNGUS AND BACTERIAL AND VIRUS DISEASES

Group	*Disease*	*Crops*
Fungi	Powdery mildews	grains, legumes, cucurbits, chrysanthemum, rose, zinnia
	Anthracnoses	beans, cowpeas, cucumbers, cantaloupes, watermelons
	Downy mildews	grasses, grains, cantaloupes, cucumbers, lettuce, onion, spinach, tobacco, violet, pansy, grape
	Leaf spots	apple scab, cherry leaf spot, rose black spot, black rot of sweetpotato
	Fusarium wilts	cotton, sweetpotato, tomato, watermelon
Bacteria	Local infections	fireblight of pear, bacterial blight of snap bean, soft rot of carrots
	Bacterial wilts	sweet corn, carnation, ring rot of potato
	Galls	crown gall
Viruses	Mosaics	potato, tomato, raspberry
	Yellows	peach, aster

Fungi with their bodies within the plant are the fusarium wilts. These minute plants live on organic matter in soils, enter the host plant body through the region of the root hair zone and attack the xylem. The xylem becomes plugged, turns brown, and the host plant wilts. Examples are: fusarium wilt of aster, cotton, sweetpotato, tomato, and watermelon.

BACTERIA

Bacteria are microscopic, one-celled, and reproduce by cell division. They vary in size and shape. Some are small and round. Others are large and rod-shaped. In general, the bacteria which cause disease on plants are short rods. They possess the faculty to live on dead and living tissue and they can enter plants only through natural openings, such as stomata, hydrothodes and nectaries, and through wounds. There are three more or

less distinct groups: (1) Those which cause local infection, (2) those which induce wilting, and (3) those which induce galls. Bacteria which cause local infection are rather specific in their action. Some produce lesions on stems and leaves, others produce cankers on woody stems, and others produce soft rots. Like the fusarium wilts, bacteria which induce wilting invade the xylem and thus disrupt the flow of water from the roots to

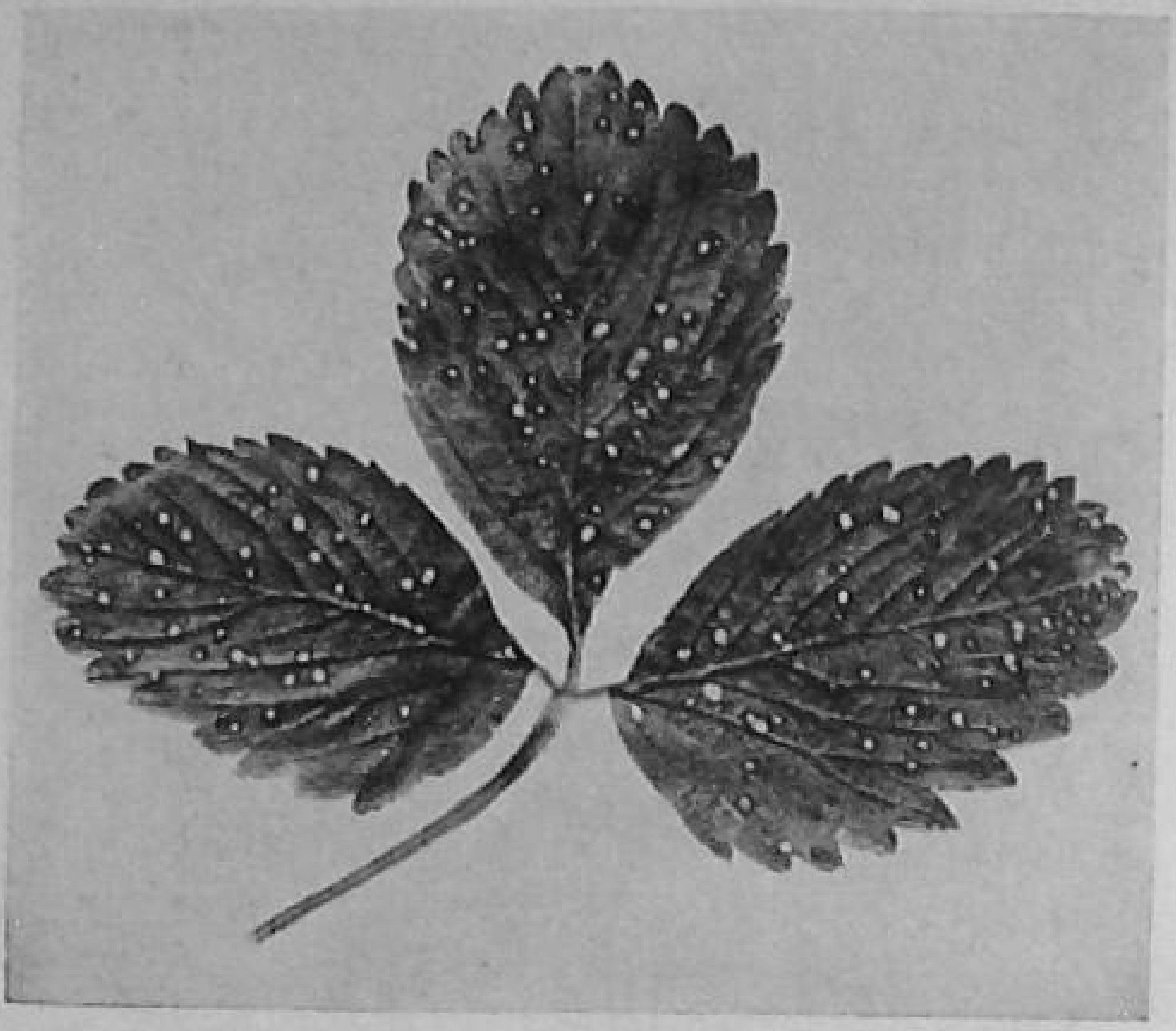


FIG. 93. Leaf spot of strawberry. (Courtesy, John T. Presley, Mississippi Agricultural Experiment Station.)

the leaves, and bacteria which induce galls cause a rapid rate of cell division. Examples of each of the three types of bacterial diseases are shown in Table 22.

VIRUSES

Viruses are considered to be large protein molecules. Under the electron microscope they look like short slender rods. Inside the plant these molecules possess the ability to reproduce themselves. Outside the plant they do not possess this ability. For example, if a molecule of the tobacco virus is injected into a healthy tobacco plant, this molecule will multiply millions of times and produce the virus disease. On the other hand, if the molecule is placed in a test tube containing nutrient substances, it does not multiply and produce the disease. There are two types of virus diseases: (1) The mosaics and (2) the yellows. In the mosaics certain areas in the leaf blade become yellow while the remainder remain green, and in the yellows the entire leaf blade becomes yellow. In either case, since

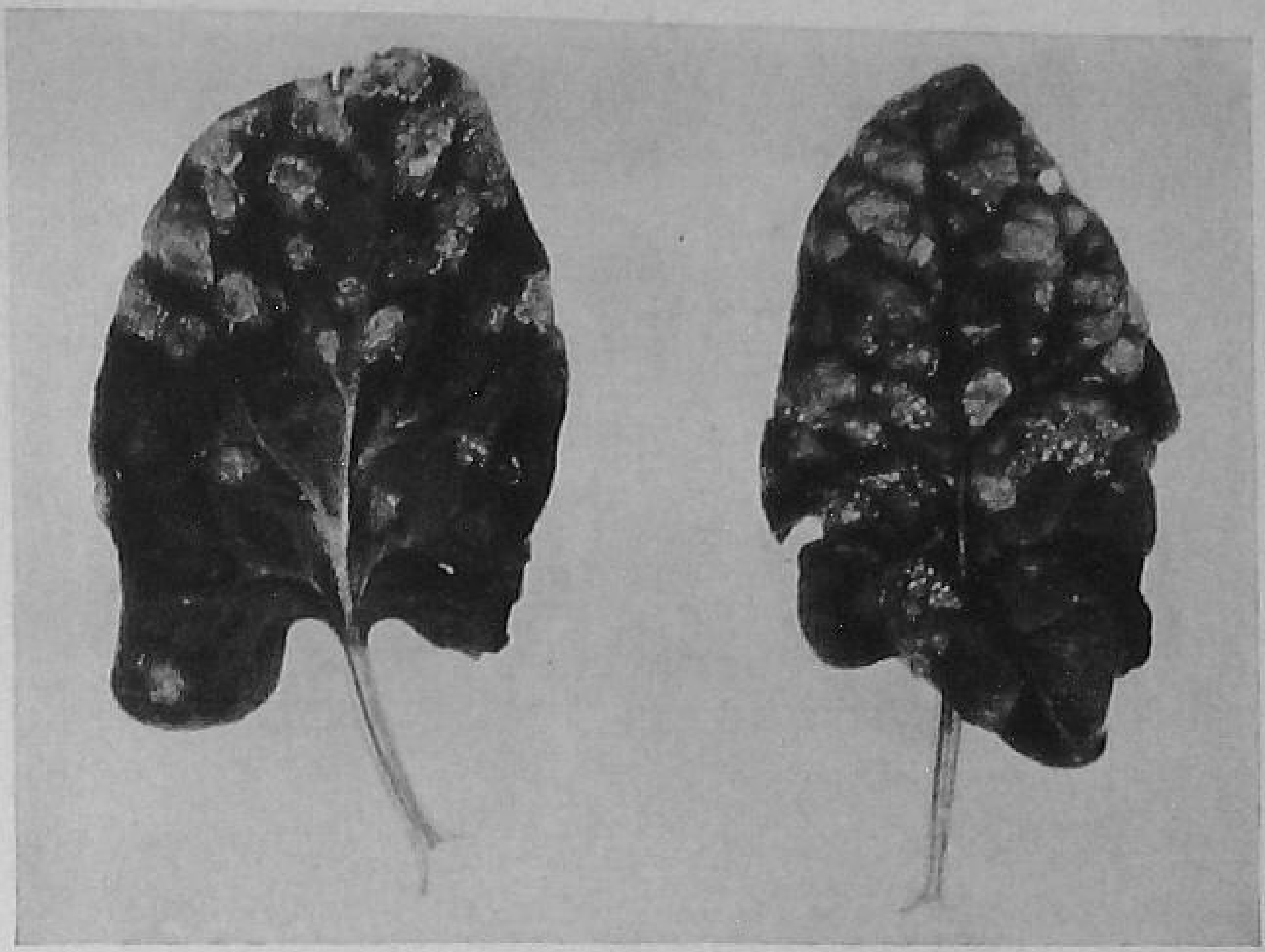


FIG. 94. White rust of spinach. (*Left*) Upper side. (*Right*) Lower side. (Courtesy, S. S. Ivanoff, Mississippi Agricultural Experiment Station.)

FIG. 95. Tomato mosaic. (*Left*) Mosaic-infected plant. (*Middle*) Healthy leaf. (*Right*) Mosaic-infected leaf. (Courtesy, John T. Presley, Mississippi Agricultural Experiment Station.)

the chlorophyll content is reduced, photosynthesis and yields are correspondingly reduced. Examples of virus diseases are presented in Table 22, and illustrated in Figures 95 and 96.

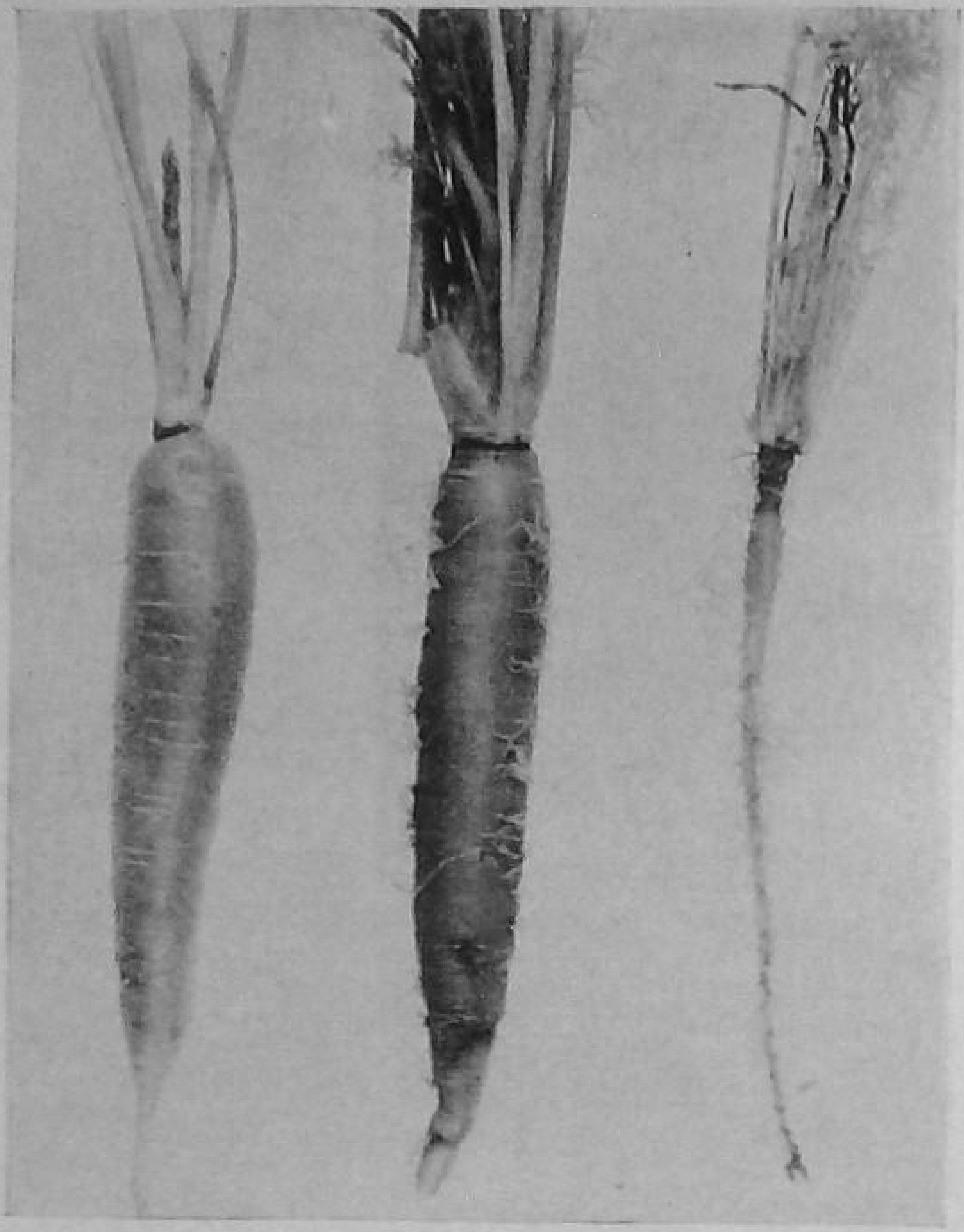


FIG. 96. Aster yellows on carrot. (*Left*) Healthy plant. (*Middle*) Moderately infected plant. (*Right*) Severely infected plant. (Courtesy, S. S. Ivanoff, Mississippi Agricultural Experiment Station.)

Questions

1. All animals including man, most fungi, and most bacteria are dependent on green plants for their existence. Explain.
2. Horticulturally speaking, what is a pest?
3. Man always has been seriously concerned about his food supply. Explain.
4. Distinguish between insects, mites, and nematodes.
5. What is the difference in feeding habits of insects with biting mouth parts and insects with sucking mouth parts?
6. How do mites lower the rate of photosynthesis and decrease yields?
7. Describe the action of nematodes.

8. Given a tomato plant wilting from 10 A.M. to 4 P.M. only. Examination of the roots show galls or swellings. State the pest.
9. Nematodes are less prevalent in northern United States than in southern United States. Explain.
10. Distinguish between fungi and bacteria.
11. Distinguish between powdery mildews and downy mildews.
12. Fusarium wilts cannot be controlled by the use of sprays and dusts. Explain.
13. Distinguish between fusarium wilt and bacterial wilt.
14. How do virus diseases reduce growth and yields?
15. Distinguish between the mosaics and the yellows.

Assignment 22

METHODS OF CONTROL

As stated before, horticultural crops are attacked or penetrated by certain insects, mites, nematodes, fungi, bacteria, and viruses. In order that any pest may grow and develop three conditions must be fulfilled: (1) The pest responsible for the damage must be present, (2) the environment must be favorable for the spread of the pest, and (3) the crop must be susceptible. Insects and diseases, therefore, may be controlled by practicing any one or more of the following measures: (1) Eliminating or eradicating the causal organism, (2) maintaining health and vigor of the crop, (3) maintaining an environment unfavorable for the development of the organism, and (4) growing resistant varieties.

Eliminating the Causal Organism

Eliminating the causal organism involves: (1) Removal of the organism from seed or plants, (2) crop rotation, and (3) crop sanitation.

Removal of the Organism. Removal of the organism may be secured with a specific lot of seed, a plant or tree, or a large group of plants. As an example, consider the control of black rot of cabbage. The causal organism is a bacterium which lives on the coat of the seed and on organic matter in the soil. Soaking the seed in hot water at a temperature of 122° F. for 25 minutes followed by rinsing in cold water eliminates the bacterium from the coat of the seed. Unless the bacterium is present in

the soil after the seed or seedlings have been planted, the crop will be entirely free of the disease. As a second example, consider the control of citrus canker. Citrus canker was at one time a serious disease of oranges, lemons, and related fruits in Florida. This disease was controlled permanently by promptly removing and burning all trees that showed the disease. As a result, citrus trees in Florida now are free from canker because the causal organism no longer is present. As a third example, take the production of certified seed of potatoes. Many varieties of potatoes are susceptible to many kinds of virus diseases—mild mosaic, rugose mosaic, leaf roll, and spindle tuber are examples. These viruses impair the capacity of the plant to make chlorophyll. As a result, the rate of photosynthesis is low. These viruses are present in the sap of infected plants and are carried from plant to plant by insects. Control of the virus diseases, therefore, consists of controlling the insect carriers combined with prompt removal of plants showing symptoms of any of the virus diseases. Certified seed of the potato are tubers which are practically free from several viruses or mosaic diseases. During the growing season the plants which are raised for certification are inspected frequently, and all infected plants are removed and destroyed. The removal of infected plants prevents the disease from spreading to healthy plants, and permits the raising of a crop of tubers which are practically free from the several virus diseases.

Crop Rotation. Crop rotation consists of the growing of a group of crops in a definite sequence on the same land. In other words, a definite period is allowed to elapse before the crop is planted again. In this way, the insect or disease organism is starved out. In general, crop rotation is most effective in controlling pests which live in the soil for a short time only. It has little or no effect on organisms which live in the soil for a period of 10 to 25 years. For example, the spores of club root of cabbage can live in the soil for 2 years only. Consequently, if the land is kept free of crops and weeds of the cabbage family for 2 years after a cabbage crop has been grown, the land will be free of this disease. On the other hand, a short rotation is ineffective in the control of fusarium wilt of watermelons, since the wilt fungus lives in the same soil for a period of 20 to 25 years.

Crop Sanitation. Crop sanitation consists of: (1) Removing promptly insect-infested and diseased plants and (2) plowing under refuse immediately after the harvest. Both methods of sanitation assist in controlling pests in the following way. Prompt removal of insect-infested and diseased plants assists in reducing and may, in many cases, entirely prevent the dissemination of the pest. It is particularly essential in controlling pests

of crops which are grown close together and in quick succession—as in the raising of plants in greenhouses, hotbeds, and cold frames. Plowing under plant remains reduces the multiplication of fungi and bacteria in the plant and soil. It is generally practiced to control pests of crops grown in the field.

Maintaining Health and Vigor of the Crop

Healthy plants, like healthy animals, possess the ability to ward off insects and diseases. Healthy plants are grown only in a favorable environment. If for any reason the environment retards growth, the plants become weak and many organisms can attack the plant more successfully. For example, the spores of powdery mildew can attack many horticultural plants. These spores are always present in most greenhouses and other plant growing structures. If the plants become checked in growth due to improper watering, excessive heat or cold, or lack of nutrients, particularly nitrogen, they become susceptible to the spores of the fungus. On the other hand, if the plants are kept in good health, the plant possesses the ability to resist the spores of the fungus. Other examples could be cited.

Creating an Unfavorable Environment for the Pest

The creation of an environment unfavorable for the growth of pests consists largely of the use of chemicals. Man has developed a large number and variety of chemical compounds for the control of insects and diseases.* These chemicals are classified according to their principal use as follows: (1) Stomach poisons, (2) contact poisons, (3) contact and stomach poisons, (4) fumigants, (5) seed treatment materials, and (6) fungicides and/or bactericides.

Stomach Poisons. Stomach poisons are used to control insects with biting mouth parts. Thus, applications should be made just before the insect begins to feed and the poison should remain on or adhere to the tissues until the insect has fed. Stomach poisons are certain arsenicals and fluosilicates. The *arsenicals* contain arsenic. Materials used are: lead arsenate, calcium arsenate, and magnesium arsenate. Of these, lead arsenate and calcium arsenate are the more widely used. In general, lead arsenate possesses greater adhesive properties and induces less injurious effects on foliage than calcium arsenate. However, calcium arsenate is more effective per unit quantity. The arsenicals are applied either as a spray or dust. In

*None is ideal and entirely satisfactory. Thus, the search for more effective and economical compounds goes on unabated.

general, sprays are used in the orchard and either sprays or dusts are used in the vegetable garden. When dusts are used, the arsenical is diluted to the proper strength with hydrated lime. The *fluosilicates* contain fluorine. Compounds used are Dutox (barium fluosilicate) and cryolite (sodium aluminum fluoride). Investigations at the Tennessee Experiment Station indicate that these compounds effectively control the flea beetle and the cucumber beetle. Like the arsenicals the fluosilicates are applied as a spray or dust. Dusts with 1 part to 3 or 4 parts of talc or sulfur usually are used.

Contact Poisons. These poisons are used to control insects with sucking or rasping mouth parts. Thus, applications should be made just as the insect begins to feed and the poison should adhere to the body of the insect. Contact poisons are oil emulsions and nicotine sulfate. *Oil emulsions*—mixtures of oil, water, and an emulsifying material—are used in rather dilute concentration, from 0.5 to 6.0 per cent of oil, particularly for the control of scales and mealy bugs. There are two types: (1) The so-called summer oils used for plants in full leaf and (2) the so-called dormant oils used on plants in the non-growing season. These types vary in kind of oil, mineral or organic, viscosity, and percentage of unsulfonated materials. In general, summer oils are more refined, have a lower viscosity and higher percentage of unsulfonated materials than dormant oils. *Nicotine sulfate* contains nicotine. This compound volatilizes as a gas, enters the breathing pores, and kills the tissues. The principal environmental factor influencing rate of volatilization is temperature. In general, the higher the temperature, between 50° and 90° F., the greater is the rate of gas formation. Thus, during the spring and fall nicotine sulfate will be more effective during the middle of the day than during the early morning or late afternoon. This material is applied either as a spray, usually 1 part to 600 parts of water, or as a dust, usually 1, 2, or 3 per cent in hydrated lime. Nicotine sulfate is used mostly for the control of aphids.

Contact and Stomach Poisons. These poisons are rotenone, pyrethrum, DDT, and sabadilla. All of these compounds are organic in nature and gradually lose their effectiveness, either while in the package or after their application. *Rotenone* is derived from the roots of certain legumes which grow in the tropics. Plants of *Derris elliptica* and of *Lonchocrapus* are important sources. The roots, finely ground, contain about 4 per cent rotenone. This chemical may be applied in the form of a dust or a spray. An effective dust contains from ¾ to 1 per cent rotenone. Materials used to reduce the rotenone content to ¾ or 1 per cent are clay, tobacco dust, flour, and sulfur. A combination of rotenone and sulfur has been found

to effectively control cabbage worms, the Harlequin cabbage bug, the Mexican bean beetle, and the tomato worm. *Pyrethrum* is made of the dry flower parts of a plant called pyrethrum. The poisonous compounds are pyrethrins and constitute about 1 per cent of most pyrethrum. Pyrethrum may be applied as a dust or spray. Tests at various experiment stations have shown that cabbage worms can be controlled effectively by this material. Its high price has limited its use. *DDT*, dichlorodiphenyl trichloroethane, was developed by a German scientist in 1874. As is well known, this material was used extensively by the armed forces in World War II to control typhus and malaria. During and since World War II extensive experiments have been conducted to determine the place of DDT in the control of insects of horticultural crops. In general, these tests have shown that DDT satisfactorily controls codling moth worm of apple, Oriental fruit moth worm of peaches, corn ear worm in sweet corn, thrips on onions, cabbage worm, and thrips, white fly, cutworms, and leaf rollers on many herbaceous flowering plants. *Sabadilla* is a toxic compound found in the seed of sabadilla, a plant which belongs to the lily family. Although the place of sabadilla in insect control has not been definitely determined, tests, particularly at the Wisconsin Experiment Station, have shown that this material applied as a dust effectively controls the bugs—squash bug, Harlequin cabbage bug, cinch bug—insects which are comparatively resistant to other contact insecticides.

Fumigants. Fumigants are chemical compounds which change from either the solid or liquid form to the vapor or gaseous form. This vapor or gas plugs up the breathing pores and thus suffocates the insect or kills the cells of the fungus or bacterium. Common fumigants are: certain cyanates, carbon bisulfide, paradichlorobenzene, and ethylene dichloride, special materials for greenhouse use, formaldehyde, chloropicrin, methyl bromide, DD mixtures, and ethylene dibromide. *Cyanates,* usually sodium, potassium, or calcium cyanide, when combined with sulfuric acid, give off hydrocyanic acid gas. This gas is used principally in the control of aphids and white fly in greenhouses and in the control of scales and mites on citrus trees. *Carbon bisulfide* in commercial form is a liquid which rapidly volatilizes on exposure to the air. This gas, which is heavier than air, is used principally in the fumigation of seed storage houses and for the control of weevils in peas and beans. *Paradichlorobenzene* and *ethylene dichloride* are crystalline solids which are used extensively in the control of peach tree borer. In the fall a definite amount of the chemical is placed at the base of each tree and covered with 1 or 2 inches of soil. The exact time of

application and the amount that should be used for each tree have been definitely established for each commercial district by the local experiment station. *Special materials for greenhouse use* are nicotine powders, azobenzene, fulex, and parathion. These materials are used to control aphids, white fly, red spider and mealy bug—some of the most troublesome pests in the greenhouse. Each material has definite and specific requirements for its use and application. Thus, directions from competent authorities should be followed carefully.

Formaldehyde is a deep, penetrating disinfectant and is applied to soil in the form of a liquid or dust. If the liquid form is used treatment consists of: (1) Spading or loosening up the soil to be treated, (2) applying ½ gallon per square foot of a solution containing 1 part of commercial formaldehyde in 50 gallons of water, (3) covering the soil with boards, burlap or paper for 24 hours, and (4) removing the cover and allowing the soil to air out for 2 or more weeks. If the dust form is used treatment consists of: (1) Mixing 8 ounces of 6 per cent dust with each bushel of soil, (2) planting the seed, and (3) watering thoroughly the soil and seed. *Chloropicrin, methyl bromide, DD mixtures and ethylene dibromide* are used principally for the control of nematodes, although these materials have certain insecticidal and fungicidal value. Each material has advantages and disadvantages. In general, chloropicrin, the tear gas of World War I, and methyl bromide are the more effective as nematocides and fungicides but are more expensive and require a wet seal to confine the gas within the soil. On the other hand, DD, a mixture of dichloropropane and dichloropropene, are less effective as nematocides and fungicides but they are not as expensive and do not require a water seal. As with other chemicals, research staffs of chemical companies and agricultural experiment stations have developed machines for their application.

Seed Treatment Materials. The principal seed treatment materials are corrosive sublimate, red copper oxide, zinc oxide, and Semesan. *Corrosive sublimate* is mercuric chloride. The poisonous principal is mercury (Hg). Mercuric chloride is available in tablet, powder, or crystalline form. A 1 to 1000 solution, 1 ounce of the chemical in 7.5 gallons of water, is used to treat the seed of many vegetable crops, the tubers of the potato, the roots of the sweetpotato, and the corms of gladiolus. The student should bear in mind that corrosive sublimate is very poisonous to animals if taken internally. It should be kept out of reach of chickens, animals, or irresponsible persons. *Red copper oxide* is offered in two forms, the red and the yellow. Red copper oxide is used as a dust to protect seed and seedlings

from injury by soil borne organisms, particularly the fungi which cause "damping off." Investigations at New York (Geneva) Experiment Station have shown that many vegetable and flower seeds can be protected adequately against "damping off" by this chemical. Dosage varies with the kind and size of seed, the moisture content of the soil, and the amount of organic matter in the soil. *Zinc oxide* contains zinc. A trade name is Vasco 4. *Semesan* and *Semesan Jr.* are organic compounds containing mercury. Like red copper oxide and zinc oxide, Semesan is used to protect seeds against "damping off." For use of all of these compounds the directions on the package should be followed closely.

Fungicides and/or Bactericides. These are placed in three groups: (1) Compounds containing copper, (2) compounds containing sulfur, and (3) certain complex organic compounds.

Compounds Containing Copper. These are Bordeaux mixture, copper-lime dust, and certain "insoluble" coppers. *Bordeaux mixture* consists of copper sulfate, hydrated lime, and water. The copper sulfate supplies copper which when in solution on the plant's surface kills the germinating spores of fungi and the cells of bacteria. The lime neutralizes any copper in solution which would otherwise injure the tissues of the plant. The strength of Bordeaux mixture is expressed in pounds of copper sulfate and pounds of fresh hydrated lime in 50 gallons of water. Common formulae are: 4–4–50, 3–4–50, 2–3–50, 2–2–50, and 4–2–50. The first number indicates the pounds of copper sulfate, the second number indicates the pounds of fresh hydrated lime, and the third number indicates the gallons of water. Bordeaux mixture is used to control many diseases. Examples are scab and black rot of apples, black rot and downy mildew of grapes, early and late blight of potatoes, early and late blight of celery, and septoria leaf spot of tomatoes. It is sometimes called the standard fungicide.

Copper-lime dust is a dry form of Bordeaux mixture. It consists of a mixture of monohydrated copper sulfate and fresh hydrated lime. Proportions usually used are 15 to 20 parts of monohydrated copper sulfate to 80 to 85 parts of hydrated lime. In general, this mixture is easier to apply and more expensive to use than Bordeaux mixture. *"Insoluble" compounds of copper* have been developed to take the place of Bordeaux mixture. Although Bordeaux mixture controls certain diseases, it markedly increases the transpiration rate of many horticulture crops—cucumbers, cantaloupes, tomatoes, beans, and carrots. Bordeaux mixture will, therefore, induce harmful effects on these crops, particularly when conditions are favorable for a high rate of transpiration. Examples of insoluble com-

pounds of copper are yellow copper oxide, copper oxychloride, and basic copper sulfate.

COMPOUNDS CONTAINING SULFUR. These are lime sulfur, colloidal or wettable sulfur, and sulfur dust. Of these lime sulfur is the most important and the most widely used. *Lime sulfur* is a solution consisting of 1 part of quicklime and 2 parts of sulfur and water. The lime and sulfur are cooked until the solution attains a rich amber color. The material is applied in two concentrations, the winter and the summer. The winter concentration consists of 1 gallon of the stock solution in 8 gallons of water, and the summer concentration consists of 1 gallon of the stock solution in 40 gallons of water. The winter concentration is applied to trees during the dormant season to control San Jose scale of apples and peaches and peach leaf curl. The summer concentration is applied to plants during the growing season. Principal diseases controlled are scab and bitter rot of apples. *Colloidal or wettable sulfur* is sulfur treated to make it disperse readily in water. A number of wettable sulfurs are available on the market. They are used according to directions on the package. The rate is usually 3 to 4 pounds

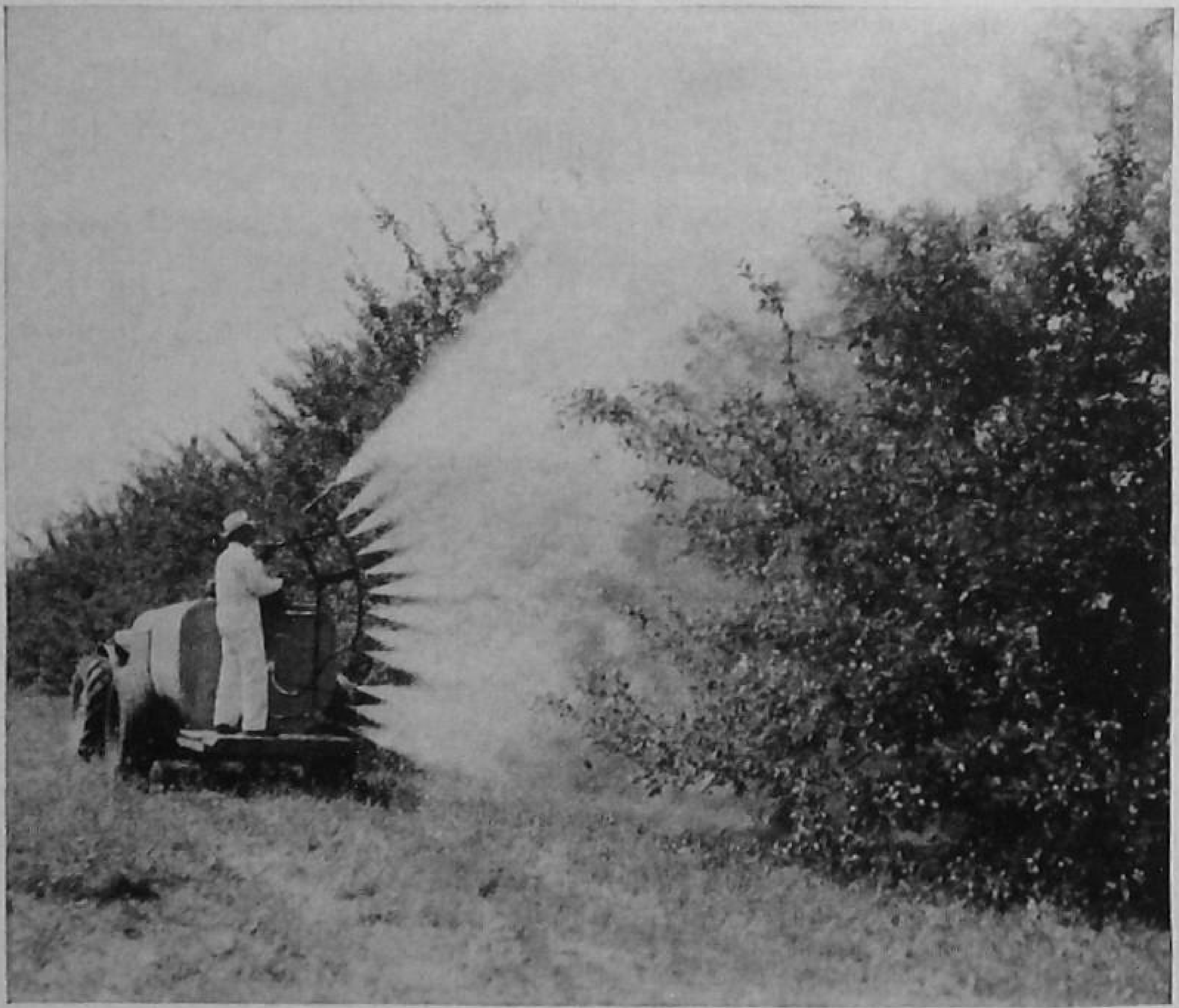


FIG. 97. Spraying an apple orchard.

FIG. 98. Spraying a tomato field.

to 50 gallons of spray. *Sulfur dust* consists of finely divided forms of sulfur mixed with lime, talc, gypsum, or other inert material. An effective dust should be sufficiently fine that 90 per cent of the material passes through a 325 mesh screen. Sulfur dusts are used to control powdery mildew of beans, roses, and other crops.

COMPLEX ORGANIC COMPOUNDS. Principal complex organic compounds are dithane and parzate. These materials are comparatively new and their place in disease control has not been definitely determined. Recent tests show that dithane controls late blight of potatoes and blossom blight of azalea.

Many chemical compounds have unfavorable effects on the fundamental processes, particularly on photosynthesis and transpiration. For example, tests have shown that Bordeaux mixture, lime sulfur, and certain oil emulsions markedly reduce the rate of photosynthesis of the apple and that Bordeaux mixture markedly increases the rate of transpiration of many herbaceous plants—tomatoes, cucumbers, cantaloupes, and carrots. These effects are undesirable and have led to the development of other less injurious materials and to an intensification in the breeding of resistant varieties. Figures 97 and 98 show two types of sprayers in operation: The one for trees in the orchard, and the other for large areas of herbaceous crops.

GROWING OF RESISTANT VARIETIES

The growing of resistant varieties is a most practical method of pest control. The buying and applying of chemicals is unnecessary, the rate of

photosynthesis is not reduced and the rate of transpiration is not increased. Thus, great economies are effected and high marketable yields are obtained. Within the past 15 years considerable emphasis has been placed on the development of resistant varieties. Examples of horticultural crops are presented in Table 23.

Table 23

RESISTANT VARIETIES OF CERTAIN CROPS

Crop	*Variety*	*Resistant to:*
Pear	Baldwin, Pontotoc	Fireblight
Peach	*Shalil, *Yunan	Nematode (certain strains)
Potato	Katahdin, Kennebec	Mild mosaic
Onion	White Persian	Thrips
Squash	African	Vine borer
Tomato	Pan American	Fusarium wilt
China aster	Tilford	Fusarium wilt
Gardenia Thunbergii		Nematode
Snapdragon	Outdoor varieties	Rust

*Used as stocks.

Questions

1. State the three conditions necessary for the spread of insects and diseases.
2. What is meant by elimination of the causal organism?
3. Crops in greenhouses are usually markedly free from disease, while the same crops grown outdoors frequently show disease infection. Explain.
4. What is certified seed of the potato?
5. In the production of certified seed of the potato, control of insects is essential. Explain.
6. How does crop sanitation control pests?
7. What are the limitations of crop rotation in pest control?
8. In your opinion how do healthy plants ward off insects and diseases?
9. Stomach poisons are used for insects with biting mouth parts. Explain.
10. Generally, lead arsenate is used in orchards and calcium arsenate is used in vegetable gardens. Explain.
11. What is the main difference in time of application of stomach poisons and contact poisons?
12. What are the advantages and disadvantages of DDT as an insecticide for horticultural crops?
13. Nicotine sulfate is more effective during high temperatures than during low temperatures. Explain.

14. Of the insecticides developed by man, rotenone most closely approaches the ideal. Give three reasons.
15. State the purpose of using seed treatment materials.
16. State the ingredients of Bordeaux mixture.
17. How does Bordeaux mixture control plant diseases?
18. How does lime sulfur control plant diseases?
19. What is colloidal or wettable sulfur?
20. Reduction in photosynthesis is a distinct disadvantage in the use of Bordeaux mixture, lime sulfur, and oil emulsions. Explain.
21. Select three chemicals which can be used for the control of insects and diseases in the home orchard, vegetable and flower garden. Give reasons for your selection.
22. How are nematodes controlled under field conditions?
23. The development of nematode resistant varieties of garden crops is particularly necessary for home gardens in the South. Explain.
24. The use of resistant varieties is the most practical method of pest control. Give three reasons.

15

Preservation

Assignment 23

The various methods of preservation are: (1) Storing, (2) canning, (3) drying, (4) pickling, and (5) quick freezing. These methods are distinctly beneficial both from the standpoint of the producer and the consumer. In general, products are made available during the entire year and gluts on markets are avoided. As examples consider peaches and sweetpotatoes. Fresh peaches are available on the markets of the United States from May to September. There are no fresh peaches available from October to April. The canning, quick freezing, and drying of peaches during the harvest season makes the fruit available, not only from October to April, but also during the entire year. The harvest season for sweetpotatoes in the United States extends from August to November. If all of the roots were placed on the market immediately after the harvest, gluts would take place. This would result in low prices and very few roots would be available from November to September. Many other examples could be cited. Since storing, canning, drying, pickling, and quick freezing affect respiration and transpiration differently and have distinct crop requirements, they are discussed separately.

STORING

The storing of plant products in their natural state is an important practice. Millions of bushels of fruit, millions of bushels of vegetables, and large quantities of flowers are stored annually. The student should re-

member that horticultural products in storage are alive, that storing consists of maintaining an environment where life processes proceed at a minimum, and that the principal processes concerned are *respiration* and *transpiration*.

Respiration

Since products in storage are alive, their living cells respire to secure energy. The equation for respiration follows:

$$\text{Stored foods} + H_2O \longrightarrow \text{soluble foods} + \text{oxygen} \xrightarrow{\text{(enzymes)}} CO_2 + H_2O + \text{heat and other forms of energy}$$

A comparatively large number of factors influence the rate of respiration of products in storage. These factors are divided into two groups: (1) Plant factors and (2) environmental factors.

PLANT FACTORS

Amount of Sugars Available. Scientists have shown that the soluble sugars, particularly glucose, are the chief sugars used in respiration. Hence, with other factors favorable, the greater the concentration of soluble sugars within the living tissues, the greater is the rate of respiration. The effect of storage temperature on potatoes shows how soluble sugars may become the principal factor affecting respiration. At 32° F., the potato tubers become sweet, that is, comparatively large quantities of sugar are formed at the expense of starch. Because of the relatively greater concentration of sugars in the tubers stored at 32° F. than in potatoes stored at 40° F., the potatoes stored at 32° F. will respire at a greater rate than those stored at 40° F. when they are placed in higher temperatures—as is usual in marketing operations.

Number of Living Cells. Because living cells require a constant supply of energy and because respiration liberates the necessary energy, the rate of respiration will be directly proportional to the number of living cells. Thus, 2 bushels of apples will require more energy and will produce more carbon dioxide and liberate more heat than 1 bushel. For the same reason, a cabbage or lettuce head will respire more rapidly in the same environment than a potato tuber or sweetpotato root. In fact, the greater the number of living cells in proportion to the dead cells of a product, the greater will be the amount of carbon dioxide and water given off.

Water Content of the Tissues. In general, the rate of respiration varies directly with the water content of the product. For example, at the Okla-

homa Experiment Station, various kinds of vegetable products were stored at 3° C. for a period of 26 hours. The succulent vegetables lost 10 to 13 per cent of their dry weight while moderately succulent vegetables lost only from 1 to 2 per cent of their dry weight. Obviously, succulent products respire more rapidly, weight to weight, than relatively non-succulent products. Thus, lettuce heads will respire more rapidly than potatoes or sweetpotatoes or even peppers. This means that immature fruit will respire more rapidly than mature fruit.

ENVIRONMENTAL FACTORS

Temperature. In general, with other factors in favorable supply and with the temperature from 10° to 35° C. the van't Hoff rule applies. That

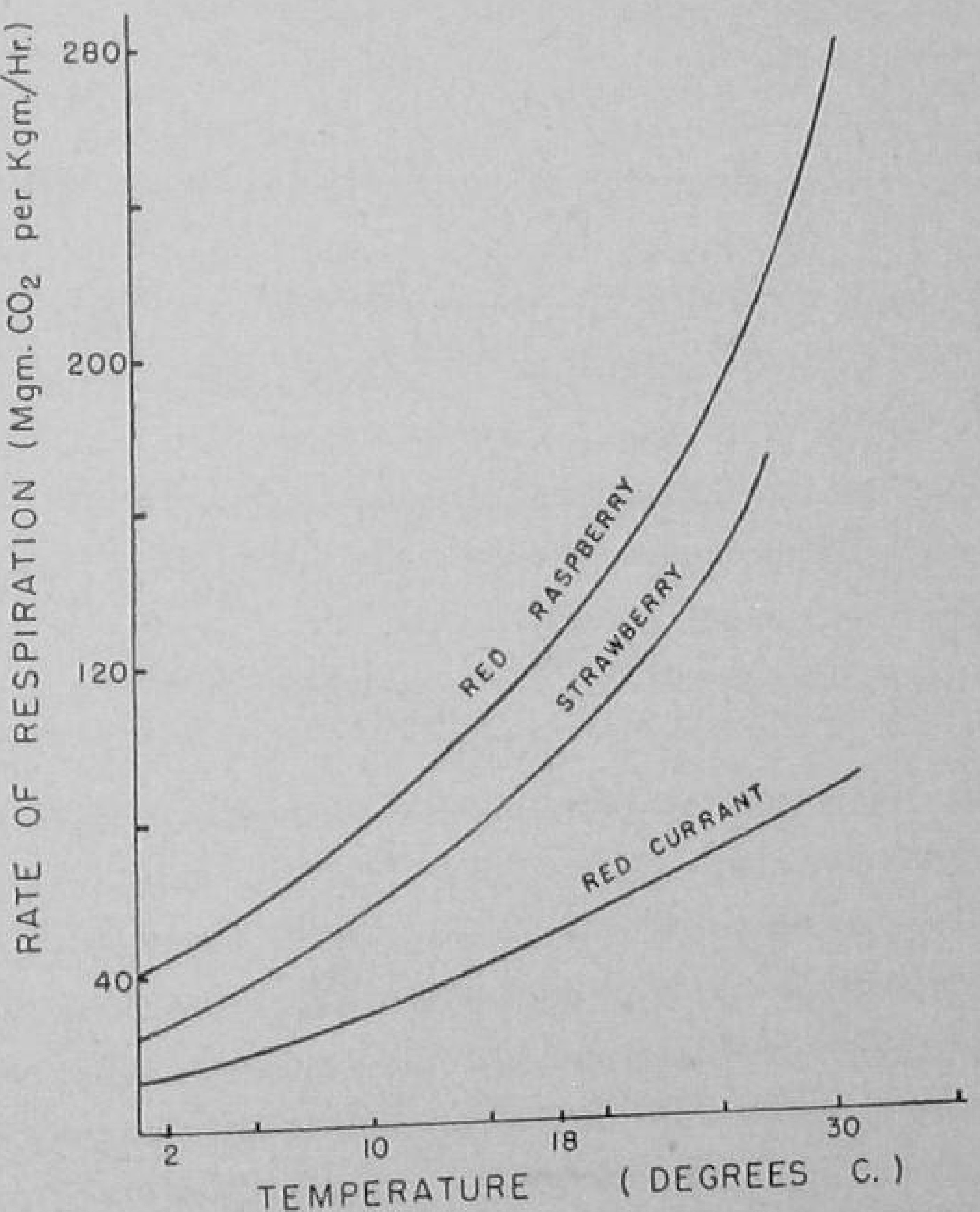


FIG. 99. Influence of temperature on rate of respiration of strawberry, raspberry, and currant.

is, the higher the temperature from 10° to 35° C. the greater the rate of respiration. In storage the respiration rate should proceed at a minimum. Note the effect of temperature on the respiration rate of the red raspberry, strawberry, and red currant as shown in Figure 99. The curves show that

the rate of respiration varied directly with the temperature. In other words, the higher the temperature, within 0° C. and 35° C., the higher was the respiration rate. Numerous investigations have shown that practically the same situation exists with other products. From these studies optimum storage temperatures of many products have been determined. Examples are shown in Table 24.

Table 24

STORAGE TEMPERATURES OF CERTAIN PRODUCTS

Storage Temperature				
32°–35° F.	35°–36° F.	40°–45° F.	45°–48° F.	55°–65° F.
strawberry, raspberry, blackberry, blueberry, celery, onions, root crops	apple, pear, peach, plum	potato	cut flowers	peppers, squash, pumpkin, sweet-potato

Oxygen Supply. As previously stated, respiration requires atmospheric oxygen. Adequate supplies actually will conserve the sugars. Consider the following equations:

$$(1)\quad \underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2 \xrightarrow{\text{Respiration with abundant oxygen}} 6CO_2 + 6H_2O + 677.2 \text{ cals. of heat energy}$$

$$(2)\quad C_6H_{12}O_6 \xrightarrow{\text{Respiration with no atmospheric oxygen}} 2C_2H_5OH + 2CO_2 + 24\text{–}28 \text{ cals. of heat energy*}$$

These equations show that for every molecule of glucose lost in abundant atmospheric oxygen about 26 molecules are lost without atmospheric oxygen in order to obtain practically the same quantities of energy. In other words, the sugars will be unnecessarily depleted when the amount of oxygen available is inadequate for the complete combustion of the sugars to carbon dioxide and water. When inadequate supplies of atmospheric oxygen are available, chemical compounds are formed which are injurious to the tissues. For example, with inadequate oxygen potato tubers develop blackheart, certain varieties of apples develop storage scald, and cabbage and celery show speckling and pitting of the petioles and veins. Thus, every storage house or room should be supplied with sufficient oxygen for normal respiration.

*From Thomas, Merrion: "Plant Physiology," Philadelphia, The Blakiston Company, 1935.

Liberation of Heat. The equation for respiration shows that heat is liberated. In the storage of certain products the liberation of heat is a vital factor, particularly with products which have a high respiration rate. As an example consider celery. Investigations have shown that the temperature of plants inside the storage crates is always higher than that on the outside. This high temperature is undoubtedly due to the lesser flow of air around the stalks in the center of the crate. Consequently, where relatively large amounts of heat are given off in storage adequate quantities of air are necessary to carry the heat away. For this reason storage in bulk is generally less satisfactory than storage in various types of containers. This is particularly true for products which have a high respiration rate.

Transpiration

The student will recall that transpiration is the evaporation of water from living plant tissues and that water is formed in respiration. Consequently, products in storage transpire water and the amount lost may be wholly or partially replaced by the water formed in respiration. For any given unit of time, for example 1 hour, 1 day, or 1 week, the amount lost by transpiration may be equal to, greater, or less than the amount made by respiration. In general, when the amount lost is equal to the amount made, little if any shrinkage takes place; and when the amount lost is greater than the amount made, shrinkage takes place and the degree of shrinkage is roughly proportional to the amount of water lost. Since shrinkage is undesirable a study of the factors which influence the rate of water loss is necessary. These factors are divided into two groups: plant factors and environmental factors.

PLANT FACTORS

Water Content of the Tissues. Plant products differ in the degree of differentiation of their tissues and hence they differ in the rate of transpiration under the same conditions. In general, non-differentiated, very succulent tissues contain more water than highly differentiated non-succulent tissues. Under the same conditions tissues with a high water content lose water more rapidly than tissues with a low water content. Examples of highly succulent tissues are asparagus spears, young spinach leaves, and young turnip greens. Examples of highly differentiated products are mature cabbage heads, onions, and celery.

Type of Outer Cover. Two kinds of tissues constitute the outer cover of plant products. These are the epidermis and the periderm. The student

will recall that the epidermis consists of a single layer of living cells. On the outer walls a layer of wax may or may not be present. Since a layer of wax on the epidermis retards transpiration, plant products with a cutinized epidermis will shrink less rapidly in storage than those with a non-cutinized epidermis. Examples of products which have an epidermis are asparagus spears, spinach, and other vegetables grown for their leaves.

The student will also recall that the periderm consists of several layers of compact, dead, cork-like cells. This tissue is admirably adapted to keep the all-important water within the product and disease organisms outside of the product. Experiments have shown that plant products with a well-developed and non-injured periderm lose water less rapidly and keep longer in storage than those products with a poorly developed or badly injured or bruised periderm. In fact, long storage life of many products depends on the maintenance of a healthy and intact periderm. Plant products which possess a periderm as the outer cover are apples, pears, citrus fruits, root crop vegetables, sweetpotatoes, potatoes, and gladiolus corms.

ENVIRONMENTAL FACTORS

Temperature. The student will recall how temperature influences the rate of transpiration of a growing plant. Since products in storage transpire, the influence of temperature on their rate of transpiration is much the same as that of growing plants. In other words, the rate of transpiration of products in storage is roughly proportional to the temperature. Thus, a comparatively high storage temperature will induce a greater rate of transpiration and greater shrinkage than a comparatively low temperature. Since a high rate of transpiration and excessive shrinkage is undesirable, comparatively low temperatures in storage houses are maintained.

Relative Humidity. By relative humidity is meant the amount of water vapor in the air compared to the amount of water vapor when the air is fully saturated for any given temperature. Thus, when the relative humidity is 50 per cent the air contains only one-half as much moisture as it would contain if it were saturated for any particular temperature. The student will recall the effect of relative humidity on the rate of transpiration of growing plants. As might be expected, its effect on the transpiration of products in storage is in much the same way. Thus, with other factors of the storage environment in favorable supply, the rate of transpiration is inversely proportional to the relative humidity. In other words, a low relative humidity induces a high rate of transpiration and a high relative

humidity induces a low rate of transpiration. Since a high rate of transpiration induces excessive shrinkage, and since excessive shrinkage is undesirable, a comparatively high relative humidity is maintained in storage houses.

In most crops, experiments have shown that the relative humidity should vary between 70 to 85 per cent. If the humidity is lower than 70 per cent, shrinkage is likely to become excessive. On the other hand, if the humidity is greater than 85 to 90 per cent, environmental conditions become favorable for the condensation of moisture on the surface of the stored products and for the development of storage rots.

Horticultural products classified according to their humidity requirements follow: fruits 80 to 85 per cent; beets, carrots, parsnips, salsify, turnips, radishes, celery, cabbage, potatoes, and sweetpotatoes 75 to 85 per cent; onions, beans, squash, and pumpkins 70 to 75 per cent; cut flowers 80 per cent; flowering bulbs 60 to 70 per cent.

Types of Storage Structures

Types of storage houses may be classified according to the degree of temperature control. These are: (1) Refrigerated and (2) non-refrigerated. *Refrigerated* storage houses have insulated walls and doors, and the temperature within the house is thermostatically controlled. Substances commonly used to maintain low temperatures are freon, methyl chloride, and ammonia. These gases are compressed and are released through pipes or coils in the storage rooms. On expansion they take up the heat of respiration. The main advantage of this type of storage is that the temperature is thermostatically controlled. Since temperatures are controlled the relative humidity can be controlled also. In this way ideal storage conditions can be maintained. The stored product has a low rate of respiration and transpiration both of which are conducive to long storage life.

Non-refrigerated storages have temperatures which are not thermostatically controlled. In other words, the temperature of this type of storage is influenced by the outside air temperature. Examples are: specially constructed houses, house cellars, pits, trenches, or mounds. Specially constructed houses have insulated walls and doors, properly spaced vents, and false floors. In the operation of these houses ventilation is essential. The function of the lower vents is to bring in cool air and oxygen for respiration, and the function of the upper vents is to carry away the heat of respiration. Large quantities of cabbage, potatoes, and sweetpotatoes are stored in this type of storage house. The storage room in house cellars, pits,

FIG. 100. A modern sweetpotato storage house. (Courtesy, Chesley Hines, Mississippi Agricultural Extension Service.)

and mounds is used mostly for storing of products of the home garden. In general, the room in the basement should have outside ventilation, a dirt floor, and shelves. The vents allow cool air to enter and warm air to escape from the storage room. The dirt floor permits a gradual evaporation of water thus maintaining a high humidity, and the shelves provide for the storage of a large number of products. Figure 100 shows a modern sweet-potato storage house located in Mississippi.

CANNING

Canning is a form of food storage or preservation. Essentially, canning consists of subjecting the plant product to high temperatures, usually from 200° to 240° F. for 5 to 90 minutes, depending on the kind of product, degree of maturity, and size of can used. The fundamental process con-

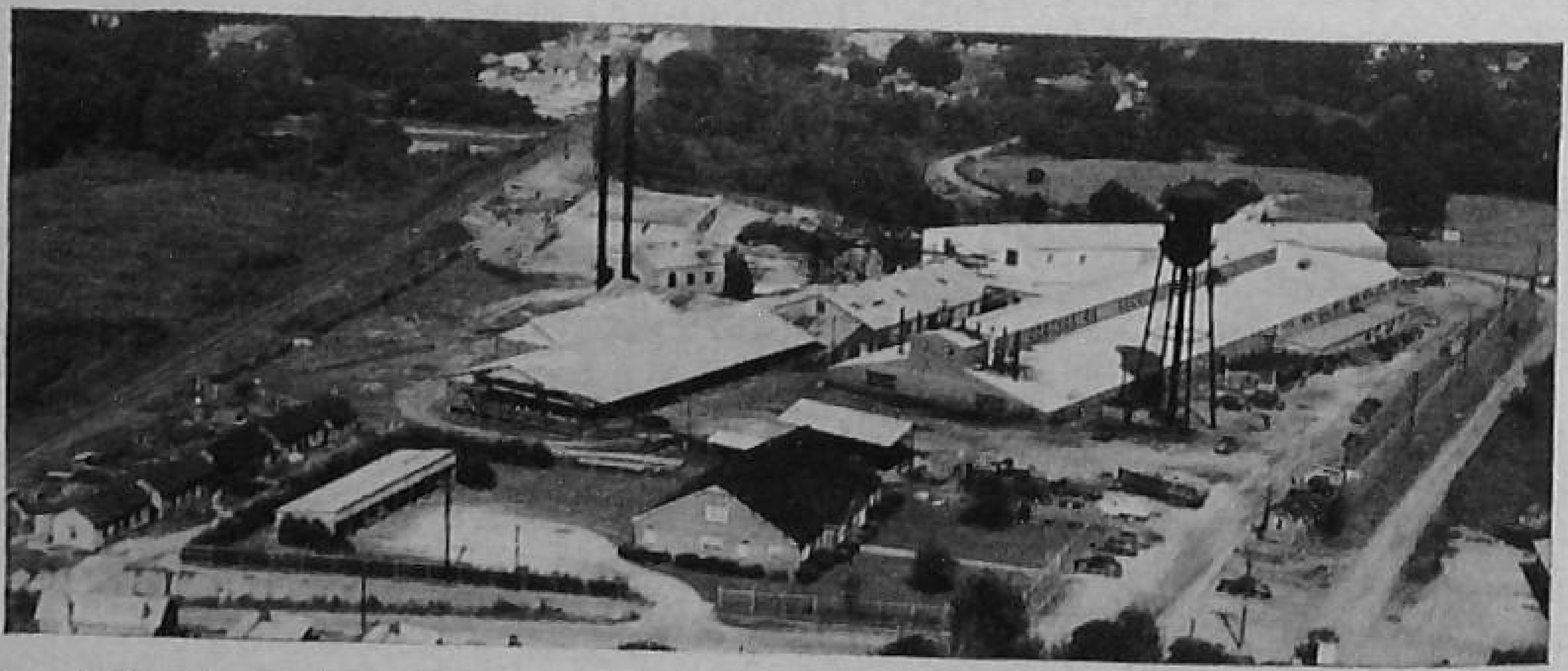


FIG. 101. A modern canning plant located near Griffin, Georgia. (Courtesy, H. L. Cochran, Pomona Products Company.)

cerned is respiration. The high temperature inactivates the enzymes. When the enzymes of respiration are destroyed the process ceases. With the cessation of respiration the sugars, proteins, minerals, and vitamins are conserved. Naturally, the shorter the time between harvesting and processing, the lesser will be the utilization of starches and sugars in respiration.

The canning of fruits and vegetables is an important horticultural industry. In fact, with many crops the acreage given over to canning is greater than that given over to growing the crop for market in the fresh state. Examples are peaches, tomatoes, sweet corn, and lima beans. Figure 101 shows a modern canning plant near Griffin, Georgia.

DRYING

Drying, technically called dehydration, is the oldest method of preservation. As the name suggests drying consists of removing sufficient water from the product to prevent it from spoilage in storage. As with other forms of food preservation the principal process concerned is respiration. The removal of most but not all of the water inactivates the enzymes for respiration. In this way the product is conserved. In general, horticultural products are dried in two ways: (1) Drying under natural conditions and (2) drying artificially. In either case the drying is done by means of warm, relatively dry air. To prevent spoilage of the product the rate of drying is relatively rapid.

Drying under Natural Conditions. This process is sometimes called sun-drying. Principal environmental factors concerned are: (1) The degree and amount of sunshine and (2) the temperature and dryness of the air. In general, the greater the intensity and duration of sunlight, the higher the temperature, and the drier the air, the greater will be the rate of drying of plant products. Thus, warm-dry climates characterized by abundant sunshine will be more favorable to sun-drying than warm-moist and cold-dry climates. Of the commercial crop-growing regions in the United States, the climate of certain intermountain areas of California is particularly favorable for the production and sun-drying of many horticultural crops. In this region large quantities of raisins, prunes, apricots, peaches, figs, and pears are produced. The winters are sufficiently cold to bring the trees out of the rest period; the springs and early summers are sufficiently warm to permit the production of large quantities of high quality fruits; and the late summers and falls are sufficiently warm and dry to permit rapid drying of the fruit. In these intermountain valleys most of the rains occur during the winter and spring, the summers are practically dry.

Drying Artificially. Drying artificially consists of heating air and passing of heated air over the product. The principal factors concerned are: (1) Temperature and dryness of the air and (2) velocity of the air. Heating of the air is necessary to increase its drying capacity. For example, within the temperature range for drying, an increase from 20° to 30° F. will double the water-holding or drying capacity of the air. Thus, the higher the temperature, without impairing the quality of the product, the greater will be the rate of drying and the lesser will be the reduction in quality. In general, the optimum temperature for drying depends on the type of product and its initial water content. For example, the optimum temperature range for apples and pears varies from 130° to 165° F. and for beans and peas from 115° to 140° F. For any one product the lower limit of the temperature range is used when drying begins, and the temperature is gradually increased to the upper limits as drying proceeds.

PICKLING

Pickling is a form of food storage or preservation. Essentially, pickling consists of placing the plant product in a salt brine mixture of definite concentration. The salt brine mixture inactivates the enzymes and in this way stops respiration. Horticultural crops which are grown for pickling are cucumbers, cabbage, onions, and beets. Special varieties of these crops have been developed for the purpose of pickling. Most of the acreage is located in northern United States. Michigan is foremost in the production of cucumbers for pickling, and New York and Wisconsin are outstanding in the production of cabbage for sauerkraut manufacture. Numerous pickling and salting stations are located in these states.

QUICK FREEZING

Quick freezing consists essentially of exposing fruits and vegetables to very low temperatures, minus 40° to 50° F. If plant products are subjected to temperatures just below the freezing point of water, water is drawn from the cells, and large ice crystals form between the cells and puncture their walls. When the product thaws the contents of the cells, sugars, vitamins, and mineral salts leak away. On the other hand, if plant products are subjected to temperatures from minus 40° to 50° F., water is not drawn out of the cells and very small crystals are formed, about one hundredth of the size of the slow frozen crystals. These crystals are packed tightly together and fail to rupture the cell walls. Thus, with quick freezing the foods, vitamins and minerals are retained. The fundamental process con-

cerned is respiration. The low temperature stops all enzymatic activity, and the all-important sugars, minerals, salts, and vitamins are conserved. Investigations have shown that the vitamin content of frozen foods compares favorably with the fresh product.

An important factor for success in quick freezing horticultural products is the growing of suitable varieties. Investigations have shown that not all kinds of fruits and vegetables are adapted for quick freezing, and that certain varieties within a given kind are unsuitable. Products adapted to quick freezing are: strawberries, raspberries, blueberries, asparagus, and certain varieties of peaches, plums, grapes, snap beans, lima beans, peas, and sweet corn.

Questions

1. State two advantages of storing, canning, drying, pickling, and quick freezing.
2. State the principal processes concerned in storing.
3. Write the equation for respiration.
4. In general, the lower the respiration rate the longer the storage life. Explain.
5. Horticultural products in storage always decrease in dry weight. Explain.
6. Given two lots of potatoes. Lot A was stored at 32° F.; lot B at 40° F. Which lot respired at the greater rate when removed to a temperature of 70° F.? Give reasons for your answer.
7. Two bushels of apples or potatoes will produce more carbon dioxide and require more oxygen than one bushel. Explain.
8. In general, vegetable crops high in moisture respire at a greater rate than those moderately high in moisture. Explain.
9. Given two lots of apples. Lot A was stored in a cellar; lot B was stored under refrigeration. In your opinion which lot would give off the greater quantities of carbon dioxide for a period of 50 days? Give reasons for your answer.
10. Show how the accumulation of heat in the storage house increases the respiration rate of horticultural products.
11. Given two lots of garden peas stored for 3 days. Lot A was stored at 40° F.; lot B at 70° F. Lot B became inedible; lot A remained sweet. Explain.
12. Abundant oxygen actually conserves sugars in stored products. Explain.
13. Products in storage are usually higher in temperature than the air of the storage room. Explain.
14. State the functions of the top vents and the bottom vents in storage houses.

15. With the lower vents open and the top vents closed in sweetpotato storage houses, the temperature of rooms filled with stored products rises. Explain.
16. Many products are stored in slatted crates. Explain.
17. In general, products with an intact periderm transpire less and have a longer storage life than those with a broken periderm. Explain.
18. Most horticulture products are stored at a relatively high humidity. Explain.
19. If cold storage is not available will tree fruits keep better for a short period on the tree or off the tree? Give reasons.
20. The warm-dry climate of the Pacific Coast is particularly favorable for the sun-drying of fruit and vegetable products. Explain.
21. What season of the year, if any, is most favorable for sun-drying in your particular community. Give reasons for your answer.
22. In general, vegetable crops are dried to a lower moisture content (5 to 10 per cent) than fruit crops (10 to 20 per cent). Can you think of any reasons for this?
23. Give two prime requirements of packages for dehydrated products.
24. How does canning, drying, pickling, and quick freezing preserve horticultural products?

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Part III

Principal Horticultural Crops

16

The Tree Fruits

Assignment 24

Tree fruits are divided as follows: deciduous and evergreen. In general, deciduous trees shed their leaves in the fall, while evergreen trees shed most of their leaves in the spring when the young leaves are expanding. Thus, deciduous trees make foods during limited periods of the year only and evergreen trees make foods the entire year. Principal deciduous tree fruits are the pomes and drupes, and the principal evergreen tree fruits are orange, lemon, grapefruit, and lime.

THE POME FRUITS (Apple and Pear)

Plant Characteristics

Root System. The root system usually consists of a relatively short tapering taproot and several large spreading lateral roots which branch into a network of smaller thread-like roots. The larger roots are woody and serve mainly for anchorage, transportation, and storage and the smaller roots are non-woody and serve as the absorbing system. The depth and spread of the roots depends largely on the texture and moisture of the soil. Where the soil is very loose and the soil moisture is deficient, the roots often penetrate many feet into the soil. In general, however, the major portion of the feeding roots is within the upper 15 inches of the soil, and the root spread is several feet beyond the tips of the scaffold branches. Thus, deep plowing or tillage will destroy many of the absorbing roots near the surface.

Stems and Leaves. The woody stem develops from alternate lateral and terminal vegetative buds. These lateral and terminal buds produce the twigs, each with a leaf and a vegetative bud at each node. As the top of the tree develops, the twigs become small branches, and finally limb or scaffold branches—the main framework of the tree. The shape of the top of mature trees varies with the species and with the variety. In general, apple trees are more or less globular, and pear trees are shaped like an inverted cone. However, certain apple varieties (Henry Clay and Delicious) have the upright habit of growth while others (Stayman) have the spreading type.

The leaves are simple, alternate, and toothed or lobed. They vary in size, shape, color, thickness, pubescence, and texture. By these differences the several species of apple and pear and certain varieties within a given species can be identified. For example, the leaves of the Baldwin variety are broad and distinctly saucer-shaped; those of the Delicious are moderately broad and U-shaped; and those of the Jonathan are small and narrow at base and apex. In general, the leaves of the pear are usually thicker, greener, less pubescent, more finely toothed, and more ovate than those of the apple.

Flowers and Fruit. The flowers are perfect, with a five-lobed calyx, five moderately large separate petals, numerous distinct stamens, and a five-celled, five-styled ovary. Five blossoms are borne from the mixed flower bud on the end of each spur. The fruit varies in shape, color, texture, size, time of maturity, and other characters. In general, apples are spherical with cavities at the basal (stem end) and apical (blossom end), and the skin is green, yellow, or red or may develop two or all three of these pigments. The flesh is white or yellow and free of grit cells. On the other hand, the pear is pyriform with less distinct basal and apical cavities, and the color of the skin varies from dull yellow in some varieties to dark reddish brown in others. The flesh is usually white or creamy white and contains numerous grit cells.

Economic Importance and Distribution

Producing Centers. The commercial production of apples in the United States is a major horticultural enterprise. In fact, this country leads all others in the production of the fruit. Principal centers of production are south and east of large bodies of water or east of mountain ranges. These afford protection from severe cold. Important commercial districts are: (1) The Shenandoah-Cumberland located between the Blue Ridge and Cumberland Mountains, (2) the western New York on the south shore of

Lake Ontario, (3) the Hudson and Champlain Valleys in southern New York, (4) the New England extending from southern Maine to Connecticut, (5) the eastern shore of Delaware and Maryland, (6) the western Michigan on the east shore of Lake Michigan, (7) the Ozark in southwestern Missouri, (8) the Wenatchee, (9) the Yakima Valley, (10) the Spokane, (11) the Walla Walla, in Washington, (12) the Hood River Valley in Oregon, (13) the Watsonville, (14) the Sebastopol in central California, (15) the Payette in Idaho, and (16) the Grand Valley in Colorado.

In the United States pears are grown much less extensively than are apples. Fireblight, a serious bacterial disease, is one of the chief limiting factors in commercial production. Important commercial districts are located in California, New York, Washington, and Oregon.

Varieties. Although about 2000 varieties of apples and about 900 varieties of pears exist in the United States, not more than eight or ten varieties of apples and not more than three varieties of pears make up the greater bulk of total production in any particular apple-producing district of the country. Varieties are selected not only on the basis of yield alone but also on other factors such as: (1) Length of the formative period, (2) length of the fruiting period, (3) susceptibility or resistance to certain pests, (4) size, color, and shape of fruit, (5) the market demand, and (6) pollenizing value. In addition varieties vary in their adaptation. For example, certain varieties such as Anoke and Northern Spy are more adapted to the northern half of the apple belt, while Early Harvest and Williams Early Red are more adapted to the southern half. In fact, the selection of varieties is a regional problem. Even within a given region the continuous development of varieties and the appearance of bud sports frequently necessitate a change in recommendations. Thus, students who are interested in varieties for certain particular areas should consult the horticultural staff of the Experiment Station or Extension Division of the state in which they are interested in growing these fruits.

Growth and Development

Climatic Requirements. The principal climatic factors are temperature, rainfall, and light. Of these, temperature is particularly important. In general, winter temperatures should be sufficiently low and prolonged to break the rest period, and at the same time they should not be sufficiently severe to damage the roots and tops of the trees. As stated in Chapter 4, a certain amount of cold is necessary to break the rest period of many

woody plants. Observations of the behavior of apple and pear trees grown in various regions of the country indicate that from 900 to 1000 hours of temperatures below 40° F. is necessary. If the trees are not exposed to sufficient cold the buds will fail to open in the spring. In general, the leaf buds require slightly more cold than the flower buds, and frequently in southern latitudes the flower buds open before the leaf buds begin to grow. Unless the leaf system develops simultaneously with, or shortly after, the opening of the blossoms the young fruits fail to set owing to a lack of necessary foods—the carbohydrates and proteins. Thus, the amount of cold necessary to break the rest period generally sets the southern geographical limits of successful commercial production of these crops.

Although apples and pears require considerable cold to break the rest period, they cannot withstand prolonged exposure to intense cold. The root system is severely injured at soil temperatures below 20° F. and unless the tops are well hardened air temperatures from minus 10° to minus 30° F. frequently injure the collar, crown, crotches, and buds of the trees. Sudden drops in temperature, particularly during late fall and early winter, usually will cause great damage. Thus, the intensity and duration of cold generally sets the northern geographical limits for the successful commercial production of these crops.

As with other crops, growing season temperatures markedly influence the amount, color, and quality of the fruit. As stated in Chapter 4 apples and pears are primarily cold-season crops. For apples the optimum temperature range seems to be from 60° to 85° F. Areas in which the average summer temperature range is above 75° F. seem to be poorly adapted to apple production. The best pear districts have a slightly higher summer temperature range than that found for the apple. With both of these crops excessively high summer temperatures undoubtedly promote a high respiration rate, this in turn lowers the amount of carbohydrates available for growth, flower bud formation, fruit development, and yield.

Soils. The ideal soil texture for apples and pears is a loam. However, loamy sand, sandy loam, and silt loam produce profitable crops, providing the subsoil is open, porous, and well drained. In no case should there be bedrock, hardpan, or waterlogged stratum within the rooting zone. Important soils are the Dunkirk of the Ontario district, the Dutchess of the Hudson River Valley of New York, the Frederick, Frankstown and Murrill of the Shenandoah-Cumberland district, the Miami and Hillsdale soils of western Michigan, the Baxter and Clarksville soils of the Ozarks, the Wind River loam of the Hood River Valley, and the Wenatchee loam of Washington.

Disposition of the Carbohydrates. Three more or less distinct though overlapping periods exist in the growth and development of apple and pear trees. These are: (1) The formative, (2) the transitory, and (3) the fruiting. During the formative or distinctly vegetative period the top-root ratio is small, vegetative growth is vigorous, and the tree uses most of its carbohydrates in the formation of new growth; thus, utilization of carbohydrates is dominant. Since the development of the stems is quite marked during this period, proper selection and training of the scaffold branches is necessary. During the transitory period the tree gradually comes into bearing. Vegetative processes are less evident, carbohydrates accumulate, flower-forming substances are made, and flower buds are formed. During this period, since utilization and accumulation of carbohydrates are more nearly balanced, excess nitrogen or heavy pruning would promote excessive vegetative growth and delay fruitfulness. Within the bearing or fruiting period there are alternating cycles of vegetative and reproductive processes. Note the diagram.

A Formative Period 1–4 years	B Transitory Period 5–8 years	C Fruiting Period 8–20 years
utilization dominant	first, utilization dominant later, utilization and accumulation balanced	alternating cycles of utilization and accumulation—with accumulation becoming dominant

When a tree begins to bear full crops vegetative growth gradually becomes less vigorous each year, carbohydrates accumulate, and reproductive processes become dominant. During this period the trees can use more nitrogen than during the transitory period. In fact, nitrogen deficiency often becomes a limiting factor in fruit production. As the tree grows older additional nitrogen and pruning are required to make utilization processes more dominant.

Principal Cultural Practices

Establishing the Orchard. Apples and pears are trained and planted according to definite systems or designs. The use of a definite plan or design is necessary to conserve the land and to promote economy and efficiency in the care and management of the trees. Principal planting systems are: (1) Rectangular and (2) contour. In the *rectangular* the trees are planted at right angles to each other with a tree at each corner of the rectangle.

This system provides for the effective use of filler varieties, permits two-way cultivation, facilitates spraying and pruning operations, and supplies maximum access of sunlight to the trees. It is principally adapted to level or slightly sloped land. Modifications of the rectangular system are the square, the quincunx, and the hexagonal. In the square the trees are set equal distances apart; in the quincunx a tree is planted in the center of each square or rectangle; and in the hexagonal all of the trees in all of the rows are the same distance apart. In the *contour* the trees are planted with the contours of the land. They are set on the contours in one direction and usually are "staggered" at definite distances in the other. Where the contour lines change direction to the extent that it is impossible to line up in parallel all of the rows in the opposite direction, a radial system of contour planting is employed. In most contour plantings the contour rows are spaced wider than the distances between the trees in the rows to facilitate spraying and harvesting operations. This system requires the use of surveying instruments to establish the contour lines and the building and maintaining of terraces. It has been designed to retard soil erosion and to permit cultivation across the slope, and is, therefore, particularly adapted to hilly or sloped land. At present the acreage of contour plantings is increasing rapidly. Note the air-view of the apple orchards in Virginia shown in Figure 102.

Pollination. As stated in Chapter 1, intervarietal pollination is necessary for fruit setting in the apple and pear. Effective pollinators should have potent and compatible pollen which is shed at the time the pistil of the variety to be pollinated is receptive. With the apple, varieties differ in these respects. For example: (1) The Winesap group (the Stayman Winesap, Winesap and Arkansas) have impotent or sterile pollen, and (2) Ben Davis and Delicious, two well-known and widely adapted varieties, have potent, compatible, and effective pollen. Thus, Ben Davis and Delicious are more effective pollinators than the members of the Winesap group. In addition certain varieties shed their pollen before or after the pistils of the main variety are receptive. For example, Rome Beauty sheds its pollen in western South Carolina after early blooming varieties are receptive. Thus, Rome Beauty is useless as a pollinator for early varieties in South Carolina orchards. With the pear, practically all varieties are interfruitful; that is, the pollen of one variety is as effective as another for pollination.

Soil Management and Nutrition. Fruit trees are cultivated and fertilized to control or to regulate the vegetative-reproductive phases of growth. As

Fig. 102. Air-view of apple orchards in Virginia. Note that the trees were planted on the contour. (Courtesy, National Fruit Company, Winchester, Virginia.)

stated before, vegetative growth should be dominant during the formative period, and a balance should be maintained between vegetative and reproductive processes during the fruiting period. Important environmental factors are: (1) Water and (2) nutrient supply. As discussed previously, the water supply can be controlled to a considerable degree by drainage, by irrigation, by the incorporation of organic matter in the soil, by regulation of the growth of the cover crop, and by weed control. The nutrient supply can be controlled by applying commercial fertilizers to supply nutrients, by cultivation to reduce competition from weeds, and by growing cover crops to reduce leaching of nutrients and erosion of soil.

In general, trees in the formative stage require clean cultivation because the root system is relatively shallow and weed competition for water and nutrients would seriously retard vegetative growth. On the other hand, trees in the fruiting period are grown either under the clean cultivation-cover crop system, the controlled-cover crop system, or the sod system of soil management. If apples are grown in your district, what is the main type of soil management used?

The use of fertilizers in the orchard has two objectives: (1) To supply the needs of the soil and cover crop and (2) to supply the specific needs of

the trees. Complete fertilizers usually are used to supply the needs of the soil and the cover crop, and quickly available nitrogen is used to supplement the supply of nitrate-nitrogen in the soil in order to adequately meet the nitrogen requirements of the trees. The amount of nitrogen required varies with the phase of growth, whether formative, transitory, or fruiting, and with the vigor of the tree during the fruiting period. In general, relatively more nitrogen will be required during the first part of the fruiting period than during the formative period and relatively more nitrogen will be required during the latter part of the fruiting period than during the former part. For example, ¼ pound of sodium nitrate or its equivalent is usually necessary for each year of growth during the formative period, from 5 to 6 pounds per tree may be necessary during the early part of the fruiting period, and from 8 to 12 pounds may be necessary during the latter part. The placement of the nitrogen is based on the spread of the branches and generally is applied to the soil in a band extending from near the trunk to a few feet beyond the tips of the branches. In this way all of the feeding roots have access to the fertilizer.

Marketing

Principal marketing operations are: picking, washing, waxing, grading, packing, and selling. *Picking* consists of separating individual fruits from the tree, placing the fruit in an appropriate container, transferring the fruit to an orchard box or crate, and transporting the fruit to a packing house or shed. The main requirement of picking operations is careful handling to reduce bruising to a minimum. A popular picking container is the metal picking bucket with a canvas drop bottom. The sides are strong enough to protect the fruit, and the receptacle is easily carried and emptied. *Washing* consists of bathing the fruit in a dilute solution of hydrochloric acid to remove spray residue from the outer cover. *Waxing* consists of applying a coat of wax on the skin to retard transpiration and shrinkage in storage and on the market. *Grading* consists of separating the fruit into market classes or grades on the basis of size, shape, and color according to the variety. *Packing* consists of placing the graded specimens in a definite manner or style in the market container. For example, the diagonal style of pack is commonly used in the packing of apples in boxes. With this type of pack the fruit fits snugly together and there is little danger of severe bruising. Although apples are packed in many types of containers, the types most commonly used are the 3-bushel barrel, the bushel basket, and the box. Each type has advantages and disadvantages.

Questions

1. What is the essential difference between deciduous trees and evergreen trees?
2. The depth of root penetration of an apple or pear tree depends largely on the texture and internal drainage of the subsoil. Explain.
3. Most apple-growing districts are in the Northeast, Midwest, and upper Pacific Coast regions. Explain.
4. Why are there no commercial apple districts in: (1) Florida and along the Gulf Coast? (2) North Dakota and South Dakota? Explain.
5. Apples on a commercial scale are grown on the southeast side of Lake Michigan and not on the northwest side, on the south side of Lake Ontario and not on the north side. Explain.
6. Name the periods in the growth and development of an apple or pear tree.
7. The transitory period is considered the most critical period from the standpoint of pruning and fertilizing. Explain.
8. A fruit spur usually bears in alternate years while the tree as a whole bears annually. Explain.
9. How do frosts during the blossoming period induce biennial bearing of apple varieties?
10. What are the requirements of an effective pollinator in the apple and pear orchard?
11. Although the pollen of a variety may be viable or potent it can be ineffective as a pollinator. Explain.
12. A colony of bees and an effective pollinator should be within 100 feet of every tree in the orchard, particularly during cold, wet weather. Explain.
13. Why are soil-building crops not grown in a young orchard during the summer? Explain.
14. Nitrogen deficiency in mature apple and pear trees is more common than nitrogen excess. Explain.
15. An apple tree 2 years old usually requires ½ pound of sodium nitrate or its equivalent. A tree 4 years old requires 1 pound, while a tree 16 years old requires 6 pounds. Explain.
16. Sunny days and cool nights during the fruit ripening period are particularly favorable for the production of highly colored fruit while cloudy days and warm nights are particularly unfavorable. Explain.

THE DRUPE FRUITS (Peach, Plum, Apricot, Cherry, and Almond)

Plant Characteristics

Root System. Mature trees of the drupe fruits have several large woody roots which branch into many small roots and numerous absorbing roots. In general, the root system is less extensive and less deep than that of the

apple and pear. For these reasons the trees suffer more quickly from drought or from weed competition. However, the root spread is roughly proportional to the size of the tree. Like the pome trees, the lateral spread of the roots is usually a foot or more beyond the spread of the branches.

Stems and Leaves. The stem system consists of: (1) Main or scaffold stems called limbs and (2) smaller branches and twigs from which arise shoots containing leaves, flowers, and fruit. In general, the buds are produced on current season wood. Buds are (1) lateral or (2) terminal. Lateral buds are (1) vegetative or (2) flower, whereas terminal buds are always vegetative. Both terminal and lateral vegetative buds give rise to (1) shoot growth (long) or (2) spur growth (short). The peach and almond produce shoots mostly, and apricots, plums, and cherries develop both shoots and spurs. The leaves are alternate, simple, long in proportion to width, short petioled, and finely toothed. The teeth and petiole often contain glands. In common with apples and pears, the leaves unfold about the time of blossoming and absciss after growth ceases in the late summer or fall.

Flowers and Fruit. The flowers of the drupe fruit crops have characteristics in common and characteristics in distinction. Characteristics in common are the hermaphroditic sex expression, regular arrangement of flower parts, with a five-lobed, bell-shaped, or tubular calyx, a five-petalled corolla, numerous stamens attached to the rim of the calyx, and a solitary pistil attached at the bottom of the calyx. Characteristics in distinction are the number of flowers per node and the color of the petals and length of the flower stalk. In the peach and apricot the flowers are in singles or pairs, the petals are white, pink, or red according to the variety, and the flower stalk is very short. In the plum and cherry the flowers occur in groups, the petals are white, and the flower stalk is long.

The fruit develops from ovary tissue only and varies greatly in size, shape, pubescence, color of the skin, and color and texture of the flesh. In general, peach fruits are comparatively large, subglobular and slightly grooved on one side and have a pubescent skin, firm greenish, white, or yellow flesh which either separates from or clings to the stony endocarp. Varieties which produce fruit in which the fleshy mesocarp and the stony endocarp separate on ripening are called "freestones," and varieties which produce fruit in which the fleshy endocarp and stony exocarp remain attached are called "clingstones." Plum fruits are moderately large, globular, and have a smooth skin and smooth pit. Apricot fruits are similar to peach fruits in size and shape and have a fine pubescence and smooth pit. Cherry

fruits are comparatively small, smooth, long stalked and have flesh which is either sweet or sour to the taste and small smooth pits. Fruit of the sour cherry is about ½ inch in diameter and pale red or dark red, and fruit of the sweet cherry is about ¾ inch in diameter with light yellow, red, or dark red skin, and firm flesh. Almond fruits are much compressed. The mesocarp, instead of being fleshy as in the other drupe fruits, becomes leathery and tough and at maturity separates from the stone. The kernel or seed of the almond is the edible portion.

Economic Importance and Distribution

In the United States, a large number of drupe fruit industries have developed. *Peaches* are produced chiefly in the Pacific Coast, Southeast, Northeast, and Midwest regions. The leading states are California, South Carolina, Georgia, North Carolina, and New York. In California yellow-fleshed clingstone varieties are grown mainly for canning and yellow-fleshed freestones are grown for drying. In states other than California yellow-fleshed freestones are grown for immediate consumption and for canning. *Plums* are grown chiefly on the Pacific Coast. In this region the principal varieties belong to the prune group—a type of plum high in sugar content and adapted to natural dehydration. *Apricots* are grown chiefly in California. *Cherries* are produced in two regions: (1) The Pacific Coast and (2) the Great Lakes. Sweet cherries are grown mostly in the former region, and sour cherries are grown mostly in the latter. *Almonds,* like apricots, are grown chiefly in California. The two general types or races of almonds are bitter and sweet. Sweet, edible almonds consist of two groups: (1) The hard shell and (2) the soft shell. Of these the soft shell is the more important.

Growth and Development

Climatic Requirements. The principal climatic factor in drupe fruit production is temperature. In common with the apple and pear, the drupe fruits have distinct winter and growing season temperature requirements. Within commercial drupe-growing districts winter temperatures are sufficiently low and of sufficient duration to bring the trees out of the rest period, but are not sufficiently low to damage the root or top system severely. In general, an exposure of 600 to 1000 hours of temperatures below 45° F. is necessary to break the rest period fully, depending on the species and varieties within the species. For example, American plums re-

quire more cold than peaches, and Elberta, an important peach variety, requires more cold than the variety, Babcock.

The minimum temperatures which trees can withstand varies with the crop. In general, well-hardened trees of American plums and sour cherries can withstand temperatures of about minus 30° F.; well-hardened trees of European plums and sweet cherries can withstand temperatures of about minus 20° F.; and well-hardened trees of peaches and apricots can withstand temperatures of about minus 10° F. Thus, of the drupe fruits American plums and sour cherries are the most hardy, European plums and sweet cherries are intermediate, and peaches and apricots are the least hardy. This relatively less hardiness of the peach explains why commercial peach belts in the northern regions are located on the leeward side of the large bodies of water. Examples are the peach belts on the southern shore of Lake Ontario and Lake Erie and on the eastern shore of Lake Michigan.

Optimum growing season temperatures vary also with the crop. The main centers of sour cherry production in the United States have a mean summer temperature of about 65° F., and those of the sweet cherry and plum have a mean summer temperature of 70° F. On the other hand, although peaches are grown in regions with summer temperatures as low as 65° F., the highest production and quality are obtained in regions which have a mean summer temperature of 75° F. Thus, the sweet cherry requires somewhat lower growing season temperatures than the peach or apricot. These different growing season temperature requirements partially explain why sour cherries are grown in the northern regions and not in the southern, and why peaches produce profitable crops in both regions.

Soils. As with apples and pears, the ideal soil texture for the drupe fruits is a loam. However, profitable production is secured on many soil types provided the subsoil contains no bedrock, hardpan, or waterlogged stratum in the rooting zone. Sands, gravelly sandy loams, loams, and silt loams are used. In general, peaches are better adapted to sands than are plums and cherries.

Disposition of the Carbohydrates. As with apples and pears, the life cycle of trees of the drupe fruits may be divided into three more or less distinct but overlapping periods: (1) The formative, (2) the transitory, and (3) the fruiting. During the formative period root and shoot growth is evident only; thus, during this period most of the carbohydrates that are made are utilized for vegetative processes. During the transitory period the trees continue to produce roots and shoots, and flowering and fruiting begin. During this period the trees are gradually coming into the bearing

stage, and carbohydrate utilization is less dominant and accumulation becomes more evident. During the fruiting period within any one season there is a period of shoot, flower, and fruit growth followed by a period of shoot and fruit maturation and flower bud differentiation. Thus, carbohydrate utilization is dominant during the first part of the growing season, and accumulation is dominant during the latter part.

During the productive life of the tree a close positive relation exists between the length of shoot growth in any one season and the quantity of fruit produced the following year. In general, short shoots, made by weakly vegetative trees, have single and rarely two flower buds in the nodes; moderately long shoots, made by moderately vigorous trees, have two, rarely single, flower buds at each node; and long shoots, made by extremely vigorous trees, have only vegetative buds at the nodes. Clearly, the moderately vigorous tree is the most fruitful.

Principal Cultural Practices

Establishing the Orchard. The same systems are used in planting orchards of the drupe fruits as are used with the pome fruits. The rectangular system is commonly used on fairly level land, and the contour system is necessary on sloped or hilly land. Planting distances vary with the crop. In general, peaches, apricots, and sour cherries are set from 20 to 25 feet apart; plums from 18 to 25 feet apart; and sweet cherries from 25 to 30 feet apart. Sweet cherry trees generally recover less readily from the check in growth incident to transplanting than do trees of the other crops. Figure 103 shows a contiguous group of peach orchards planted on the contour. Note how the correct distance between the rows is maintained.

Pollination. Among the drupe fruits there are wide differences in the ability of the pollen to produce satisfactory crops of fruit. These differences are due to the incompatibility of the pollen. As stated in Chapter 1, incompatibility is due to the failure of the pollen tube to grow down the style in time to liberate the sperms which unite with the egg and the endosperm nuclei. When union does not take place, the young fruit ceases to grow and dies. Two kinds of incompatible pollen exist: (1) Self-incompatible and (2) cross-incompatible. Thus, self-incompatible pollen cannot successfully "set" the fruit of the same tree or of trees of the same variety, and cross-incompatible pollen cannot successfully "set" the fruit of two different varieties. Consequently, where self-incompatibility and cross-incompatibility exist, the interplanting of suitable pollinator varieties is necessary.

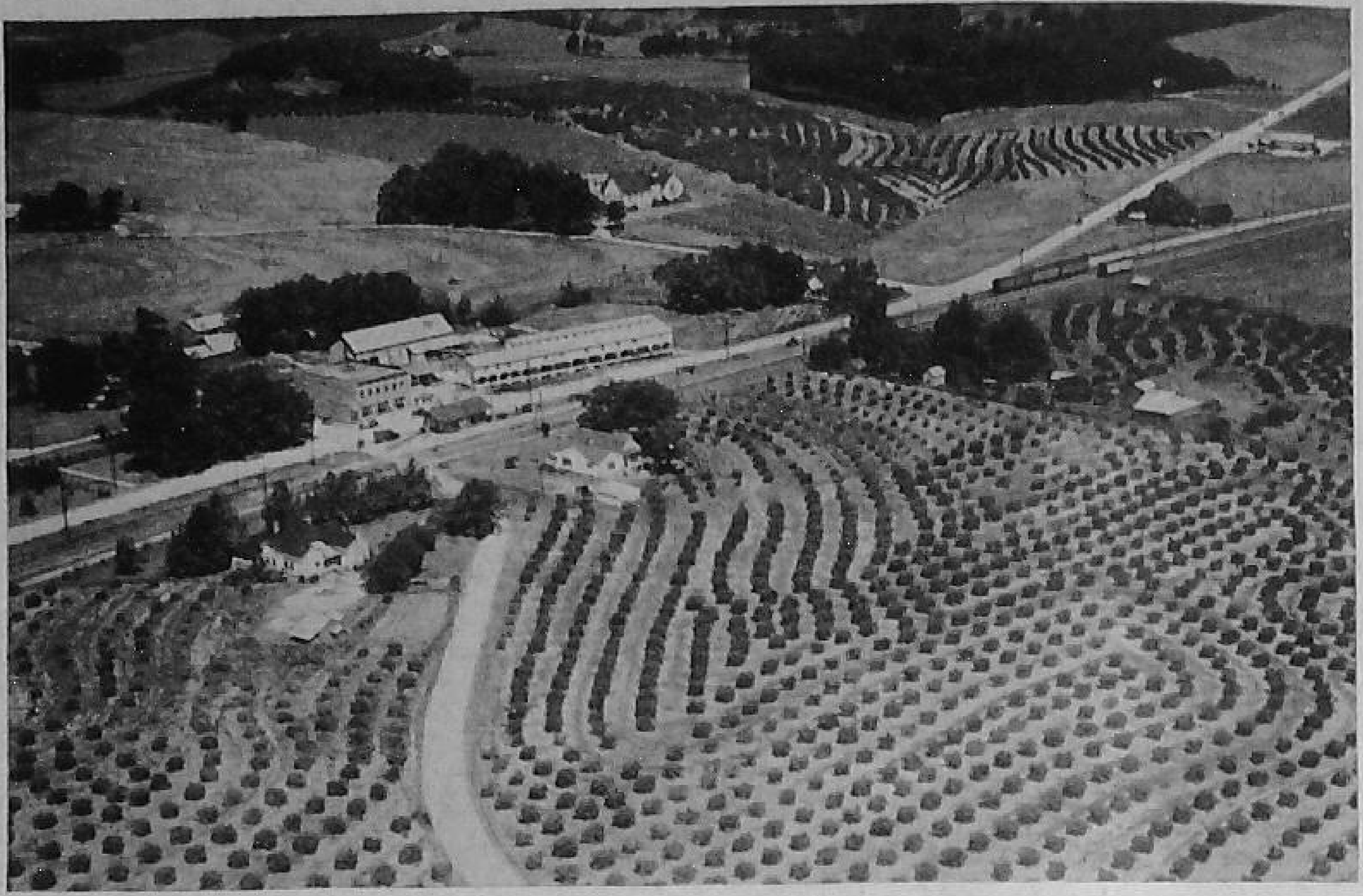

FIG. 103. Air-view of peach orchards, supply store, and packing shed in South Carolina. (Courtesy, Soil Conservation Service, U.S. Department of Agriculture.)

The situation of the drupe fruits in regard to self- and cross-incompatibility is set forth briefly as follows: in peaches and apricots all varieties are self-compatible; hence, any one variety of peach or apricot is planted in solid blocks. In plums most Japanese varieties are self-incompatible and many are cross-compatible. Thus, with the Japanese group any one variety is not planted in solid blocks but is interplanted with a cross-compatible variety. With the European group certain varieties are self-incompatible; others are self-compatible; while others are cross-compatible. Thus, solid blocks are given over to the self-compatible sorts, and interplanting is necessary for the self-incompatible sorts. In the sweet cherry most varieties are self-incompatible and some are cross-incompatible. Hence, a knowledge in suitable cross-compatible varieties is necessary. In sour cherries most varieties are self-compatible.

Soil Management and Nutrition. To produce profitable crops the drupe fruits require the controlled-cover crop system of soil management. During the spring and summer the cover crop is disked or mowed to reduce competition for water and nutrients and during early fall the cover crop is established to facilitate winter conditioning of the trees and to reduce soil erosion. With this system vigor and productivity of the trees are maintained more satisfactorily than with the sod system and the all-season, clean cultivation system.

In practically all commercial districts trees of the drupe fruits require nitrogen and in some districts in addition to nitrogen, particularly with peaches grown on light sandy soils, they require phosphorus, potassium, magnesium, and calcium. In general, the amount of nitrogen required varies with the kind of drupe fruit, the vigor and age of the trees, and soil fertility. For peaches sufficient available nitrogen is applied to induce a terminal growth of 16 to 24 inches per year. Usually ¼ pound of sodium nitrate or ammonium sulfate or a similar nitrogen carrier is sufficient for two-year-old trees and from 3 to 5 pounds are necessary for older trees. The nitrogen is applied in one or two applications. If one application is made, the nitrogen is broadcasted about 10 days before blossoming begins. If two applications are made, the first, about one half of the total, is broadcasted before blossoming and the second application is made immediately after the fruit has set. In districts where deficient nutrients other than available nitrogen are evident, applications of complete or special mixtures are made.

Marketing

The principal marketing operations are: picking, grading, packing, storing, and selling. In general, peaches for fresh market are packed to reach the consumer when the fruit is in the ripe stage of maturity. Thus, the fruit is picked in the hard ripe stage of maturity for long distance shipment and in the ripe stage for local markets. Popular market containers are bushel baskets, Jersey baskets, Georgia carriers, and climax baskets. In general, plums are picked with stems attached when fully ripe, handled carefully to retain the natural bloom, and packed much like peaches in crates and climax baskets. Cherries for the fresh market are picked with stems attached just before they are fully ripe and preferably in fair weather. A common container for sweet cherries is the quart basket. Crates containing 16, 20, 24, 30, and 32 of these quart baskets are used to transport the cherries to market. Western sweet cherries are usually packed for eastern markets in 8- or 10-pound boxes or flats.

Questions

1. How does a peach fruit differ from an apple fruit?
2. In general, drupe fruit trees are less drought resistant than pome fruit trees. Explain.
3. How does the fruit of the peach differ from that of the apricot?
4. How does the fruit of the almond differ from that of the peach?

5. Which is the leading region in peach production? Give reasons for your answer.
6. Set forth briefly the set of environmental conditions which determine the southern geographical limits for commercial peach production.
7. Peaches for commercial production are not grown along the Gulf Coast of Texas, Louisiana, Mississippi, and Florida. Explain.
8. What set of environmental conditions determines the northern limits of commercial peach production? Give reasons for your answer.
9. Peaches thrive satisfactorily in southern Michigan; they do not thrive well in central Iowa. Explain.
10. Where are most of the sweet cherries grown? most of the sour cherries? Give reasons.
11. Classify the fruiting wood of the peach according to its degree of productivity.
12. The vigor of shoot growth of the peach tree is associated with the number and kind of buds formed. Explain.
13. How can the grower determine the immediate productivity of peach trees?
14. A student goes into a peach orchard and examines two trees, A and B. The shoots of tree A have many fruit buds in twos at the node. Those of tree B are mostly single. Which tree will produce more fruit? Explain.
15. The fruiting spurs of the plum are straighter than those of the apple. Explain.
16. Given two cherry trees, A and B, each 10 years old. On tree A spurs make from 1 to 2 inches of growth each year; on tree B spurs make from 2 to 3 inches of growth each year. Which tree will be the more fruitful? Explain.
17. Would you set peach trees of the same variety at the same or at a wider distance in the row in the Delta of Mississippi as in the Sand Hill Section of North and South Carolina? Explain.

THE CITRUS FRUITS (Orange, Lemon, Grapefruit, and Lime)

Plant Characteristics

Citrus trees are broad-leaved evergreens. The trees vary in height from 10 feet (lemon) to 40 feet (orange) and to 50 feet (grapefruit). They differ little in habit of growth. When young, the trees are upright and spreading; as they grow older they become somewhat pyramidal in shape. In general, citrus trees are long-lived and begin bearing at 4 to 6 years of age.

Root System. Citrus trees are propagated by budding. This insures the production of a standard product and also provides for a more satisfactory root system. For example, the roots of the sweet orange are very shallow

and hence are not adapted to conditions of high transpiration. The principal stocks are: (1) Sour orange, (2) rough lemon, and (3) trifoliate. Of these the sour orange stock is the most widely used. The crown roots of this stock spread laterally and vertically to a considerable distance and penetrate the soil to a sufficient depth to assure an adequate supply of moisture to the tops of the trees. Rough lemon stock roots are more adapted to sandy soils and trifoliate stock roots are more adapted to well-drained, flat-wood soils. In general, they are used wherever cold resistance is needed, as in the growing of Satsuma oranges in northern Florida, southern Alabama, and southern Mississippi. All citrus root systems produce a large mass of fine roots. These function as absorptive organs and grow near the surface of the soil. Thus, the fine roots of citrus trees perform the same function as do root hairs on the roots of deciduous fruit trees and of other crops.

Stems and Leaves. The trunks are usually short and their diameter depends on the kind of crop and age of the tree. In general, most trees are headed "low." At planting, the young trees are headed-back from 18 to 30 inches to induce this "low" heading. This produces a dense to fairly open head with the lower branches drooping almost to the ground, thus bestowing protection to the trunk during cold weather. The wood is very strong and elastic. For example, heavily loaded orange and grapefruit limbs, though their normal position is from 8 to 12 feet above the ground, often bend without breaking.

The leaves are rather rough and leathery in texture, light green on the under side, and deep glossy green on the upper. They vary in shape and size according to the kind of fruit. In general, the leaves of the kumquat are small, long, and narrow; those of the sweet orange are medium, fairly broad, and long oval; and those of the grapefruit are large, long, and broad. The petioles are broadly winged, narrowly winged, or not winged, a character which serves as a means of identifying the various kinds.

Flowers and Fruit. The flowers occur singly or in groups consisting of small axillary or terminal cymes. Individual flowers have four or five white or purplish pink petals, numerous stamens, usually 20 to 40, and a single 8- to 15-celled pistil. They are extremely fragrant, which can often be detected for a considerable distance from the orchards. The size of the flower varies with the kind of plant. For example, flowers of the grapefruit are large; those of the sweet orange are moderately large; and those of the tangerine are small.

The fruit is derived from ovary tissue only and consists essentially of a leathery rind or skin (the outer portion) and of soft juicy flesh (the inner

and edible portion). The rind is derived from the outer ovary wall and has numerous oil sacs imbedded in its tissue. It varies in depth (thin to thick) and in color (light yellow to deep orange-red) depending on the kind of fruit. The rind serves as a cover and provides protection from the inner ovary wall and is divided into five or more segments by means of thin, radial, grayish membranes. Each segment is packed with large, spindle-shaped sacs which contain soluble sugars, various organic acids, and more particularly comparatively large quantities of ascorbic acid or vitamin

FIG. 104. Close-up view of orange tree. Note that the fruit is borne on the young wood. (Courtesy, Los Angeles Chamber of Commerce.)

C. Most varieties of orange and grapefruit are self-fertile and are wind- and insect-pollinated. A few, the Washington Navel orange and Tahiti lime, produce parthenocarpic fruit. Note the close-up view of the orange tree in Figure 104.

Economic Importance and Distribution

Citrus fruits are grown in many parts of the world. Important commercial industries are located in Spain, Italy, Palestine, India, China, Australia, and North and South America. In the United States the industry is foremost in value and importance and is located in the southern regions of the country. Outstanding industries exist in Orange, Los Angeles, San Bernardino, Tulare, Riverside, Ventura, and San Diego counties of southern California, in the Rio Grande Valley of south Texas, in central Florida, and in the Plaquemines district below New Orleans, Louisiana. Most of the oranges and lemons are produced in California and Florida, and most of the grapefruit are produced in Florida and Texas. Note the air-view of the citrus orchards shown in Figure 105.

Growth and Development

Climatic Requirements. In common with the deciduous nut crops, citrus and other subtropical fruits thrive best in regions between the tropics where frost or freezing temperatures never occur, and the temperate zone where freezing temperatures occur for a considerable period during the winter season. This zone is known as the subtropical zone. Within this zone growing season temperatures are usually sufficiently high for the production of profitable crops and for proper maturation of the fruit. On the other hand, winter season temperatures frequently cause the grower great concern. Unlike the apple and the peach, citrus trees are non-hardy. They can withstand only a few degrees below 32° F. For example, the critical temperature of the sweet orange is about 24° F. and that of the lemon is about 26° F. Even the Satsuma orange, the hardiest of the citrus family, cannot withstand temperatures below 18° F. In citrus-growing districts temperatures below these critical points occur frequently and orchard or grove heating, a unique practice in citrus culture, has been developed. Oil or wood burners are placed at definite intervals in the orchard, and while burning they raise the temperature of the air 8° F. or more. This increase in temperature usually is sufficient to prevent damage to the trees and fruit. Since orchard heating is an expensive practice, scientists are en-

FIG. 105. Air-view of citrus orchards in southern California. (Courtesy, Los Angeles Chamber of Commerce.)

deavoring to increase the hardiness of citrus trees by selection and breeding.

Authorities believe that about 35 inches of water are necessary for the annual production of most of the important citrus fruits. This amount of water is supplied by the rain or by rain supplemented with applications of irrigation water. In Florida most of the water is supplied by rain. It occurs mostly during the summer and applications of water may be beneficial from February, when the trees are in bloom, through June. In the lower Rio Grande Valley of Texas, the Salt River Valley of Arizona, and the

various citrus districts of California the mean annual rainfall varies from 5 to 20 inches and the deficits varying from 15 to 30 inches are made up by irrigation.

Soils. In common with other orchard trees, citrus trees require well-drained, well-aerated, and moderately fertile soils. Excellent soil drainage is particularly necessary. Soils extensively used are Norfolk fine sand, Blanton fine sand, and Orlando fine sand in Florida; Hidalgo fine sand and Victoria fine sandy loam in the Rio Grande Valley; and Fallbrooke fine sandy loam, Hanford silt loam, and Placentia silt loam in California.

Disposition of the Carbohydrates. Like the temperate tree fruits, citrus trees have three more or less distinct but overlapping phases of development: (1) The formative, (2) the transitory, and (3) the fruiting. During the formative period the young trees are developing the main branches of the root system and the framework of the tops—the trunk, primary and secondary scaffold branches. Thus, practically all of the carbohydrates are used for vegetative growth. During the transitory period the young trees continue their root and top growth, but in addition, flower buds are formed, followed by the initiation of the fruiting period. Thus, not all of the carbohydrates are used for root and stem growth; some are used for flower bud formation and for fruit development and maturation. During the fruiting period there are alternate cycles of shoot, flower, and fruit development followed by shoot and fruit maturation. In sharp contrast to deciduous trees, citrus trees develop stems and leaves two or three times each year. The period of vegetative growth takes place whenever the temperature, water, and nutrient supply are favorable. The behavior of citrus trees in Florida is shown in the following diagram.

February–March	*April–May*	*June*	*July*	
Blossoming and first cycle of shoot growth	Growth of young fruit	Second cycle of shoot growth and development of fruit	Maturation of fruit	
A	B	C	D	E

Principal Cultural Practices

Establishing the Orchard. Common planting systems for establishing citrus orchards are: (1) The square and (2) the contour. When the contour system is used, the rows are straight in one direction unless the contour of the land is quite steep and irregular. As with other fruits, planting distances depend on the kind of crop, type of soil, rootstock, and climate. In general, oranges are planted in rows from 22 to 24 feet apart with the

trees from 20 to 24 feet apart in the rows, and lemons are planted in rows from 22 to 26 feet apart with the trees from 18 to 22 feet apart in the rows. For high crop production per acre during the first part of the life of the orchard, double planting is the usual practice and the excess trees are removed when crowding occurs. In California citrus trees are planted usually from early spring to early summer and in Florida they are planted in winter or just after the beginning of the rainy season in the summer.

Soil Management and Nutrition. As with many other tree fruit enterprises, the controlled-cover crop system is necessary for the production of citrus fruits. The time during which cover crops are grown coincides with the period of heaviest rainfall. In California practically all of the rain occurs in the winter. Thus, cover crops that grow in cool weather are started in the fall just before the rains occur and are incorporated in the soil in the spring just before the rains cease. Mustards, *Melilotus indica*, malva, and natural or introduced weeds are commonly used. In Florida most of the rains occur in the summer. Thus, cover crops are started in the spring and are cut or incorporated in the soil in the fall—usually just before the harvest season. In this state warm-season crops adapted to acid soils are grown—beggar weed, velvet bean, crotalaria, all legumes—are examples.

As with other crops, the use of commercial fertilizers depends on the nutrient content of the soil and on the age, vigor, and growth characteristics of the plant. In California most soils in the citrus districts contain sufficient quantities of all nutrients except nitrate-nitrogen and available zinc. Common organic nitrogen carriers used are: manure, alfalfa hay, bean, and cereal straw, and the principal inorganic nitrogen carrier used is ammonium sulfate. The organic carriers are usually applied in the fall and the ammonium sulfate is applied near the end of the rainy season just before growth starts in the spring. Mottle-leaf due to a lack of available zinc is controlled by the application of zinc compounds to the leaves in the form of a dust and spray. In Florida and adjacent districts most soils are deficient in available nitrogen, phosphorus, and potassium and some of the soils are deficient in calcium. Thus, the fertilizer program in the Gulf Coast citrus districts consists largely of using complete mixtures and lime. Because the trees make vegetative growth two or more times each year, the practice is to apply the fertilizer at two definite periods each season, usually in February and June. For young trees, the mixture consists of 5 per cent nitrogen, 5 to 7 per cent phosphoric acid, and 4 to 6 per cent potash; and for bearing trees, the nitrogen is usually reduced 1 or 2 per cent and phos-

phoric acid and potash increased from 2 to 5 per cent. The fertilizer is usually applied at the rate of 2 to 4 pounds per tree for each year of age. In Florida only a small percentage of the nitrogen is derived from organic sources, since serious trouble, such as die back, is likely to occur when large quantities of organic nitrogen carriers are used.

Marketing

The marketing of citrus fruits is a most highly developed and efficient system. Many operations are involved. Most important are *picking* to remove the fruit from the tree; *transporting* in field boxes to the packing shed; *degreening* to destroy chlorophyll and to unmask the yellow and orange pigments; *washing* to remove spray residue, smudge, and other deposits; *drying* to remove moisture from the rind; *waxing* to reduce transpiration of the fruit and to polish the skin; *x-raying* to detect frost-damaged or granulated specimens (operators are able to see the internal structure of the fruit as it passes through a fluoroscope); *grading* according to size into three or more market classes; *stamping* of individual specimens; and *wrapping* and *packing*. Common containers are boxes, crates, and open mesh bags.

Questions

1. Name the important citrus fruits.
2. How do the size and habit of growth of citrus trees compare with those of apple and peach trees?
3. The various kinds of citrus are not grown on their own roots. Give two reasons.
4. Given two orange groves planted on a deep, porous sandy soil. Grove A is budded on sour orange stock, and grove B is budded on rough lemon stock. The latter makes the best growth. Explain.
5. Compare the life of citrus leaves with those of the apple.
6. Citrus flowers have a strong sweet scent. Compare this with deciduous fruit flowers.
7. Some citrus fruits are always seedless. Explain.
8. The rind of citrus fruits does not cling to the flesh as does the skin of the apple. Explain.
9. Florida and California grow most of the citrus fruits in the United States. Explain.
10. During the days of sailing ships, fresh vegetables and most fruits were not part of the diet of the crews of the ships, but limes, lemons, or oranges usually were found on all ships. Explain.
11. Compare the time of vegetative growth of citrus fruits with that of deciduous tree fruits.

12. In California citrus districts, cover crops are grown during the winter; in Florida citrus districts, they are grown during the summer. Explain.
13. In California citrus districts, ammonium sulfate is the most popular source of available nitrogen used; in Florida sodium nitrate is the most popular source used. Could ammonium sulfate be used with equally good results in Florida? could sodium nitrate be used with equally good results in California? Give reasons for your answer.
14. Oil heaters used in citrus culture generally are successful in preventing damage due to frosts. However, they are seldom effective in preventing damage due to freezes. Explain.

17

Grapes, and Small Fruits

Assignment 25

Grapes belong to three species: (1) *Vinifera,* (2) *Labrusca,* and (3) *Rotundifolia.* Small fruits include: the brambleberries, strawberry, currant, gooseberry, blueberry, and cranberry. Of these crops grapes, the brambleberries, and the strawberry are the most important commercially.

GRAPES

Plant Characteristics

Root System. The root system of mature vines is relatively extensive. In most well-aerated soils the roots extend from 8 to 12 feet in the horizontal direction and from 5 to 6 feet in the downward direction. Like the pomes and drupes, the primary and secondary roots are woody and are used mainly for support, transportation, and storage of carbohydrates.

Stems and Leaves. The stems are climbing, woody vines which possess tendrils, enlarged nodes, well-developed conducting tissue, and a large pith. The tendrils are modified stems and arise opposite the leaves at the nodes. The buds are: (1) Terminal and (2) lateral. The terminal buds are always vegetative and the lateral buds are either mixed or vegetative. The mixed buds give rise to flower bearing canes and the vegetative buds give rise to non-flowering canes. The leaves are simple, alternate with well-developed lobes, grooved petioles, and small stipules. They vary in size, shape, color, and number of lobes according to the species and variety.

Flowers and Fruit. The flowers are borne in clusters called panicles. These clusters arise on the basal nodes of the flower bearing shoots opposite a leaf or tendril. In *Labrusca* grapes each flower bearing shoot contains from two to six flower clusters and in other species each shoot has two clusters. Individual flowers are hypogynous and perfect with five united, greenish white petals, five reflexed or upright stamens, and a single rudimentary or functional pistil. The upright or reflexed position of the stamens and the functional condition of the pistil are important horticultural characteristics. Varieties with upright stamens produce functional pollen and varieties with reflexed stamens produce abnormal, impotent pollen. This nonfunctional, impotent pollen cannot germinate and is, therefore, useless in fruit production. The mature fruit is a moderately large, juicy, round to elongated ovary which contains relatively large quantities of soluble sugars, notably glucose or grape sugar. With *Labrusca* grapes the skin of the fruit (epicarp) readily separates from the pulp (mesocarp) and in *Vinifera* grapes the skin and pulp remain attached.

Economic Importance and Distribution

Vinifera grapes are native to southwestern Asia and have been cultivated for more than 4000 years. On the other hand, *Labrusca* and *Rotundifolia* grapes are natives of North America and were undoubtedly cultivated before America was discovered. *Vinifera*, or European grapes, are grown mainly in the Pacific Coast region, notably in Fresno, Tulare, and San Joaquin counties of California. *Labrusca* grapes are grown in the Midwest and Northeast regions, mostly in New York and Michigan, and *Rotundifolia* grapes are grown in the Southeast and Southwest, mostly in the Gulf Coast states.

Growth and Development

Climatic Requirements. The three species of grapes have climatic requirements in common and climatic requirements in distinction. All species have a rest period. Thus, they require a period of exposure to cold before growth can start promptly in the spring. Characteristics in distinction pertain to differences in growing season requirements, relative susceptibility to fungus diseases and relative hardiness. In general, *Vinifera* varieties require warm-dry weather for the development, maturation, and drying of the fruit, are susceptible to foliage diseases, and are relatively tender. Thus, the growing season for *Vinifera* grapes is warm and dry and the winters are relatively mild. *Labrusca* varieties require moderately cool weather, are

moderately resistant to foliage diseases and are very hardy. Thus, they are grown in regions characterized by cool summers and cold winters. *Rotundifolia* varieties require a long, warm growing season, are resistant to foliage diseases, and are relatively tender. Thus, varieties of this species thrive well in the Southeast region of the country.

Soils. Ideal soils for grapes are deep, well-drained, well-aerated, and moderately acid to slightly alkaline loams. In many important grape-growing districts the subsoil contains considerable quantities of gravel and shaley rock fragments. Typical soils of important districts are: Dutchess gravelly silt loam of the Hudson Valley, New York; Dunkirk gravelly loam on the Lake Erie shore of New York and Pennsylvania; Chenango gravelly loam of western New York; Baxter silt loam of the Ozarks; and Aiken gravelly loam, Pleasanton gravelly silt loam, and Placentia silt loam of California. In general, very heavy soils are avoided since they retard maturity of the fruit and have poor internal drainage.

Disposition of the Carbohydrates. For bearing vines and for any one growing season there is a period of cane growth followed by a period of cane and fruit maturation. During the period of cane growth the plants are developing their fruit bearing branches and young canes for fruit production the following year. During the period of cane and fruit maturation the plants are ripening new canes and fruit and are forming flower buds for the following year. Thus, at the beginning of the growing season practically all of the carbohydrates stored in the canes the previous season are used for vegetative processes. As cane growth subsides and maturity of the fruit begins, utilization becomes less dominant and accumulation becomes more evident. Finally, during the latter part of the growing season practically all of the carbohydrates are used for reproductive processes.

Principal Cultural Practices

Establishing the Vineyard. Both level and sloped sites are used in commercial production. For example, in the interior valleys of California level sites are common and in the Northeast and Midwest regions sloped sites are preferred. Rather wide planting distances are necessary. For *Labrusca* grapes the plants are usually set 8 or 9 feet apart in rows 8, 9, or 10 feet apart. In general, straight rows are used on level land, preferably in the north and south directions, and plantings on the contour lines are required on sloped or hilly land. About 3 years are necessary to bring a vineyard into profitable production. Principal operations are as follows: For the first year, (1) preparing the land, (2) plowing out the rows, (3)

heading-back both the roots and the tops of the young plants, (4) setting the plants, and (5) establishing a trellis; for the second year, heading-back the vines at the beginning of the growing season; and for the third year, heading-back and thinning-out the canes according to the training system desired. Figure 106 is a general view of the Delaware vineyard at State College, Mississippi. The Dog-Ridge stock on which the cions were grafted promotes vigor and productivity under southern conditions.

Pollination. From the standpoint of the functional ability of the sex organs three groups of varieties exist: Group I—varieties with functional stamens and functional pistils; group II—varieties with non-functional stamens and functional pistils; and group III—varieties with plants with functional stamens and non-functional pistils and plants with non-functional stamens and functional pistils—the dioecious varieties. Thus, from the standpoint of pollination, varieties of group I may be planted in solid blocks; those of group II require interplanting with a variety of group I; and those of group III require the interplanting of pollen-producing vines with fruit-producing vines. The majority of grape varieties belong to group I. Thus, they are self-fertile and present no pollination problem. However, as previously stated, varieties of group III belong to the species *Rotundifolia.* The plants with functional stamens and rudimentary pistils, some-

Fig. 106. The Delaware vineyard at State College, Mississippi. The cions were grafted on Dog-Ridge stock. (Courtesy, J. P. Overcash, Mississippi Agricultural Experiment Station.)

times called "mules," are interplanted, usually every third vine in every third row, with plants of the commercial variety.

Soil Management and Nutrition. In practically all grape-growing districts, the clean cultivation-cover crop system of soil management with certain modifications is practiced. Clean cultivation is necessary during the period of cane growth to reduce competition for water and nutrients, and cover cropping is necessary during the latter part of the growing season and during the winter. In the Northeast and Midwest regions the cover crops hasten the maturity of the canes, hold snow, reduce erosion, and add organic matter; and in the Southeast and Southwest regions they reduce soil erosion and leaching and add organic matter.

As with other horticultural crops, the nutritional requirements of grapes depend largely on the growth habits of the vine, the natural fertility of the soil, and the system of soil management. In general, there is a rapid development of young canes and leaves followed by the maturation of the canes and the development of the fruit. Thus, unless the soil is very fertile, applications of available nutrients, particularly nitrate-nitrogen, are necessary during the period of cane growth; and applications, usually complete mixtures, are necessary to establish and supply the needs of the cover crop.

Marketing

As stated previously, grapes are raised for raisins, for wines, for juice, and for the table. Grapes for raisins are dried, either naturally or artificially, and are marketed in boxes lined with wax paper and in paper cartons. Grape wine is marketed in bottles of various shapes and sizes, and grape juice is marketed in jars, bottles, and cans. Grapes for the table are picked in the cluster. The individual clusters are handled carefully to preserve the bloom of the individual berries and are placed in relatively small containers. The climax basket is commonly used in the Northeast and the Midwest.

SMALL FRUITS

Brambleberries

The brambleberries include: red raspberry, purple raspberry, black raspberry, blackberry, dewberry, and loganberry.

Plant Characteristics. The root system of the brambleberries is moderately extensive. Like the grape, the primary and secondary roots are woody and are used for support, transportation, and storage. The stems possess numerous terminally curved spines called "prickles" and are erect (the red

and black raspberry) or decumbent (the dewberry). As a rule these stems, called canes, have a life cycle of 2 years. During the first year they attain their growth and differentiate their flower buds, and during the second year these flower buds develop into fruit bearing shoots. When the fruit has matured, the canes die and are removed by pruning. The leaves are alternate and contain from three to five leaflets. The flowers are borne in clusters. Individual flowers are comparatively large and perfect in all kinds of varieties, except the Pacific Coast dewberry, which develops both hermaphroditic and pistillate plants. The receptacle is convex and bears numerous stamens and pistils; and each pistil develops into a small drupe or drupelet. In the raspberry the cluster of drupelets of each fruit separates from the receptacle at maturity, forming the familiar thimble-like mass of fruit. In the blackberry, dewberry, and loganberry the drupelets remain attached to the receptacle at maturity.

Economic Importance and Distribution. The bramble fruits are grown commercially in many regions of the United States. Important districts are: (1) Red raspberry—the Pacific Coast, western Washington and Oregon, and the Great Lakes, southern Michigan, western New York, and eastern Minnesota; (2) black raspberry—the Great Lakes, southwestern Michigan, western New York, northeastern Ohio, and northwestern Pennsylvania; (3) blackberry and dewberry—the Southwest and Midwest, Texas, Oklahoma, and Kentucky; and (4) loganberry—the Pacific Coast, western Oregon, and Washington.

Growth and Development. Like the different kinds of grapes, the different kinds of brambles have common and different climatic requirements. Although definite chilling requirements of these crops have not been determined, all of them require a certain amount of exposure to cold to break the rest period. However, they vary in relative hardiness and in growing season requirements. In general, raspberries are the most hardy and require relatively cool summers to produce satisfactory crops, while blackberries and dewberries are the least hardy and thrive best in the warm summer climate of the Southeast and Southwest. Thus, the raspberry industry is located in the upper Pacific Coast and the Midwest, and the blackberry and dewberry industries are located in the lower Midwest and Southwest.

In general, the brambleberries are grown on well-drained, well-aerated, moderately to slightly acid sandy loams, loams, and silt loams. Representative soils are Napanee silt loam of Michigan, Baxter silt loam of the Ozarks, Norfolk fine sandy loam of Texas, and the Everett-Alderwood-Kittsap

association of soils in the Puyallup Valley of Washington. Good air drainage is essential.

Essentially, the growth and development of the brambles consist of the development of flowers and fruit of the second year canes and of the development of new canes for the next year's crop. Thus, carbohydrate utilization is dominant during the first part of the growing season in order to develop the flowers, young fruits, and young canes. As the fruits attain maturity and young canes acquire their growth, carbohydrate utilization becomes less dominant. Thus, accumulation takes place with the formation of flower-forming hormones, the laying down of flower buds, and the maturity of the cane's tissues.

Culture. In general, two systems are used to establish and to maintain bramble fruit plantations: (1) The hedgerow and (2) the hill. In the hedgerow system, the plants are set 2½, 3, 4, or 5 feet apart in rows 7, 8, 9, or 10 feet apart. As growth proceeds, the plants form solid rows from 2 to 4 feet wide. In the hill system, the plants are set 5 x 5 feet, 6 x 6 feet, or wider spacings with one or two plants per hill, depending on the kind of crop and fertility of the soil. In both systems the clean cultivation-cover

FIG. 107. Washington red raspberries at State College, Mississippi, trained to the hedgerow system. (Courtesy, J. P. Overcash, Mississippi Agricultural Experiment Station.)

crop system of soil management is used; and commercial fertilizers, if required, are applied at the beginning of the growing season to stimulate growth of the canes and the fruit, and just before the cover crop is established to promote the rapid production of organic matter. Like the grape, a close positive association exists between the size of the cane and the size of the crop. In general, the most vigorous canes produce the most abundant crops. Note the three-wire vertical trellis used in the hedgerow system shown in Figure 107.

Mature brambleberry fruits are highly perishable and easily bruised. In general, they are picked in the early morning directly into ½-pint and quart boxes—the containers in which they are sold. Crates holding 16, 24, 32, or larger quantities of these pint or quart boxes are used to ship the different types of berries to the market.

Strawberries

PLANT CHARACTERISTICS

Root System. The root system of the strawberry is relatively shallow and moderately extensive. Studies at the Nebraska Experiment Station have shown that most of the roots extend horizontally and vertically for a distance of about 12 inches. A few roots were found between the 1- and 2-foot levels. Since the range of the root system is limited and shallow, strawberry plants are mulched in regions of comparatively high transpiration.

Stems and Leaves. The stems are short and thick and are called crowns. They bear three kinds of buds: (1) Those which develop into short thick stems called crowns, (2) those which develop into long slender stems called runners, and (3) those which develop into flowers. New plants are formed from the runners. They have long internodes and possess the ability to form a new individual at each node. Gardeners take advantage of this method of asexual reproduction in the establishment of new plantations. The leaves arise in rosettes around the short crown-like stem and are long petioled and trifoliate.

Flowers and Fruit. The flowers occur in groups or clusters. Mature individual flowers are relatively large with five or more green sepals, five or more white petals, and numerous stamens and numerous pistils distributed over a fleshy receptacle. Varieties without stamens or with only abortive ones are called pistillate varieties and require interplanting with varieties that bear functional stamens. The mature fruit is a fleshy receptacle to

which are attached a large number of small "seed-like" fruits called achenes.

ECONOMIC IMPORTANCE AND DISTRIBUTION

The strawberry is the most widely adapted of the small fruits. It is grown in Europe, in every state of the United States, and in Alaska, Canada, and South America. The principal producing centers of the United States are located in the regions east of the Mississippi River and on the Pacific Coast. The wide variation in climates within these regions and the wide adaptation of the strawberry plant permits harvesting and marketing of the fruit during the greater portion of the year. Commercial centers in southeastern Texas, southern Louisiana, central Florida, and in south, central, and northern Alabama supply markets from December to April. Producing districts in Tennessee, western, eastern, and central Arkansas, southwestern North Carolina and the Norfolk and Eastern Shore district of Virginia supply markets from April to June. Producing districts in Kentucky, Missouri, Maryland, and central California, Illinois, and New Jersey supply markets from June to July, and districts in Michigan, New York, Oregon, and Washington supply markets from July to September. Varieties adapted to the many producing districts have been developed. For example, the variety Klondike has a short rest period, is relatively non-hardy, can produce large quantities of fruit during cool weather, and endure relatively hot summers. Thus, the Klondike is adapted to the warm-humid summers and mild winters of the Southeast region. On the other hand, the variety Premier has a long rest period, can withstand mild subfreezing temperatures, and cannot endure hot summers. Thus, Premier is better adapted to the Northeast and Midwest regions.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal factors are temperature, length of day, and moisture supply. From the standpoint of temperature some varieties are tender and others are hardy. However, even with the hardy varieties, the crown on the plants is injured when the temperatures fall below 10° F. Since temperatures at the ground level are usually several degrees lower than those a few feet above the ground, the necessity for winter protection in cold climates is realized.

From the standpoint of response to length of day, strawberries are placed in two groups: (1) Varieties that develop flower buds during both long and short days—the everbearing varieties—and (2) varieties that develop

flower buds during the short days only—most commercial varieties. In the northern half of the country they form flower buds in September and October only. However, in the southern half they form flower buds both in the fall and in the spring. Thus, the southern regions provide for a larger and longer fruiting period for strawberry production than the northern regions.

From the standpoint of the water supply, since strawberries are relatively shallow rooted, they are susceptible to conditions of drought. Thus, if hot, dry weather occurs during the period of fruit maturation, and if plants are not irrigated, the size of the individual fruit is low and yields are low. If it occurs during the period of flower bud formation, yields of the following season's crop are likely to be curtailed.

Disposition of the Carbohydrates. The life of modern commercial varieties is divided into: (1) The vegetative period (usually 1 year or less) and (2) the fruiting period (1, 2, 3, or more years). During the vegetative period the young plants are developing their short thick stems and the root system. During the production period the adult plants in any one season develop in sequence: leaves, flowers, fruit, runners, and flower buds. Thus, utilization of carbohydrates is dominant during the first part of the growing season and accumulation is dominant during the latter part.

PRINCIPAL CULTURAL PRACTICES

Establishing the Plantation. In the United States various planting or training systems are used. Principal systems are: (1) The hill and (2) the matted row. In the hill system the plants are set in single, double, or triple rows and all runners as they appear are removed. In the matted row system the plants are set in a single row and the runners are allowed to root and produce additional plants. A modification of the matted row is the hedgerow, in which a definite number of runners are set by hand until the desired stand is obtained, after which all surplus runners are removed. Each system has advantages and disadvantages. In many strawberry-growing districts of the Southeast, the plants are grown on raised beds to facilitate drainage and aeration.

Soil Management and Nutrition. In strawberry production the clean cultivation-mulching system of soil management is used. In general, cultivation is necessary during the seedling stage of growth to control weeds and to promote the rapid development of stems and leaves, and mulching is necessary during the fruiting period. The mulch keeps the fruits free from soil, reduces decay of the fruit, conserves moisture, lowers soil tem-

FIG. 108. Strawberry harvesting scene near Hammond, Louisiana. Note that needles of the long leaf pine are used as a mulch. (Courtesy, J. A. Cox, Louisiana Agricultural Extension Service.)

perature in hot weather, protects flowers from frost in mild climates, and protects plants from freezing injury in cold climates. In the Southeast the mulch is usually applied just before flowering begins, and in the Northeast and Midwest it is applied just before freezing weather begins. Mulching materials used are pine needles, hay, and straw.

In most commercial districts strawberries require the application of commercial fertilizers. In general, whenever applications of fertilizer are necessary, they are applied: (1) At the time of soil preparation, or immediately after the plants have been set to promote the rapid development of the stems and leaves and (2) just prior to blossoming to increase the setting and the development of the fruit. As with many other crops, agricultural experiment stations have developed fertilizer and pest control programs for the many strawberry-producing districts. Figure 108 shows a harvesting scene in a field in the Hammond, Louisiana commercial district. Note the type of picking container, the single row system of culture, the absence of weeds, and the long leaf pine needle mulch.

MARKETING

In common with the bramble fruits, strawberries are highly perishable. Usually the fruit is picked in the early morning and sent to the market in

the afternoon of the same day, or is picked in late afternoon, stored overnight in a cool place, and sent to market the following morning. A common market container is the 1-quart basket. Ordinary shipping crates contain 24 of these baskets, and pony refrigerator crates contain 32, 64, or 80. Ventilator and refrigerator cars are used to transport this highly perishable fruit from the various regions of production to the many centers of consumption.

Currants and Gooseberries

Plant Characteristics. Currants and gooseberries form many stems which arise from many points of the root system. In gooseberries the stems possess spines or prickles and in currants they are smooth. In fruit bearing plants the crops are borne on one-year wood or on one-year-old spurs borne on two- or three-year-old wood. When the stems become 4 or 5 years old, they cease to bear fruit. Thus, productivity is maintained by removing the old stems. The leaves are alternate and palmately lobed. The inflorescence is a raceme. Individual flowers are perfect and epigygnous with four or five calyx lobes, four or five petals, four or five stamens, and a single, inferior pistil. Cross-pollination, chiefly by insects, is the rule and, with rare exceptions, all varieties are self-fertile. Like the pomes, the mature fruit consists of ovary wall and receptacle tissue. In currants ripe fruit is black, red, or white, according to the variety.

Economic Importance and Distribution. In the United States the production of currants and gooseberries is a minor horticultural crop industry. The acreage is between 4000 and 4500 and the annual production of fruit approximates 5,000,000 quarts. The principal producing districts are located in southern New York and in the Great Lakes and Pacific Coast regions.

Growth and Development. The principal climatic factors are temperature and water supply. Currants and gooseberries thrive best in regions characterized by cool weather with abundant rain or irrigation. These crops are very resistant to low winter temperatures. Hence, they are best adapted to the northern regions of the country. In the Southeast the growing season temperatures are generally above the optimum for high production, and in the Southwest the weather is exceedingly hot and dry. Currants and gooseberries require deep fertile loams, silt loams, and clay loams, since these soils are less susceptible to drought than sands and sandy loams. In bearing plants the flowers appear first in the spring followed by the production of leaves, the development and maturation of fruit, and

the production of new canes. Since the open flowers are susceptible to frost injury, growers use sites which are adequately protected and air drained.

Culture. In commercial plantings the plants are set 4 or 5 feet apart in rows 7, 8, or 9 feet apart. They require the clean cultivation-cover crop system of soil management, and in some cases applications of complete mixtures are necessary to maintain growth and vigor. The fruit is picked in clusters and marketed in relatively small containers. Quart baskets in crates are standard market containers and 6- to 8-pound grape baskets are used for the cannery. Because the fungus which produces blister rust on five-needle pines spends part of its life cycle on currants and gooseberries, this pest has practically precluded the planting of these fruits in locations where white pines are commercially important.

Blueberries*

Plant Characteristics. There are many kinds of blueberries. Six important commercial kinds or species are listed in Table 25. Note the differences in plant height, habitat, and regional adaptation. In general, the root system of blueberries is shallowly or deeply situated, according to the species and habitat, finely divided and devoid of root hairs; the woody stems develop from underground rootstocks forming suckers; the flowers are relatively small, perfect, sympetalous, and usually occur in clusters; and the fruit is a relatively small juicy ovary which, when ripe, varies from black to light blue.

Table 25

Important Species of Vaccinium (Blueberries)

Species	*Common Name*	*Plant Height (feet)*	*Habitat*	*Regional Adaptation*
V. australe	Highbush	10–15	Moist places	Atlantic Coast Plain; Midwest
V. ashei	Rabbiteye	4–8	Well drained	Southeast
V. pallidum	Dryland	1–3	Dry, well drained	Appalachian Mts.; nw. Ark.
V. angustifolium .	Lowbush	½–1½	Dry, well drained	Northeast; Canada
V. ovatum	Evergreen	20	Dry, well drained	Northwest
V. membranaceum	Mountain	3	Dry, well drained	Northwest

*The material on blueberries is contributed by Prof. W. T. Brightwell, Coastal Plain Experiment Station, Tifton, Georgia.

FIG. 109. The original plant of Calloway, a variety released in 1949. (Courtesy, W. T. Brightwell, Georgia Coastal Plain Experiment Station.)

Economic Importance and Culture. At present, most blueberries are harvested from wild plants. In fact, commercial plantings are relatively rare and consist of selected plants from two kinds only: (1) The highbush and (2) the rabbiteye. The highbush has about the same temperature requirements as the peach, requires a moist soil with a water table about 18 to 24 inches from the surface, shallow cultivation, and a pH of 4.3–4.8. Yields per plant vary from 6 to 10 quarts which ripen over a period of 4 to 6 weeks. On the other hand, the rabbiteye has comparatively low chilling requirements, grows well in relatively dry, infertile soil, and competes successfully with weeds for water and nutrients. Yields per plant vary from 20 to 30 quarts which ripen over a period of 4 to 12 weeks. In common with other horticultural crops, new varieties of blueberries are being developed. Figure 109 shows the original plant of Calloway, a new variety adapted to southern conditions.

CRANBERRIES

There are two types of cranberries: (1) The highbush and (2) the lowbush. The highbush is used as an ornamental plant and is not grown commercially to any great extent. The lowbush is the large fruited cran-

berry which is grown commercially—chiefly in Massachusetts, New Jersey, Wisconsin, Washington, and Oregon.

Plant Characteristics. The cranberry, like the blueberry, has a mass of fine, fibrous roots which possess no root hairs. A fungus, called mycorrhiza, is associated with the roots and undoubtedly aids in the absorption of water and nutrients.

The lowbush cranberry is a vine type evergreen plant with upright stems which vary from ½ to over 1 foot in height. Uprights, about 6 inches in height, are most desirable as they produce large crops and facilitate picking of the fruit. The stems possess the ability to form roots wherever they come in contact with the soil.

Culture. In the United States about 28,000 acres are grown and about 600,000 100-pound barrels are produced. Principal producing districts are: the Cape Cod area of Massachusetts with 14,000 acres and the Coastal Plain area of New Jersey with 11,000 acres. Small areas exist in Wisconsin, Washington, and Oregon. The principal varieties are Early Black with deep red fruit and Howes with light red fruit.

The growing of cranberries is a highly specialized industry and the crop requires rather unique cultural practices. Suitable bogs are sandy, relatively level, and close to a body of fresh water. The bogs are first cleared, graded, and ditched. The ditches have several purposes: to insure ade-

Fig. 110. A 3-year-old cranberry bog in northeastern United States. (Courtesy, C. M. Chaney, American Cranberry Exchange.)

quate drainage during the growing season, to flood the land to float off fallen berries, to protect the plants against low temperatures, and to help control insects. The bog is established by planting cuttings in hills and the plants are ready for their first harvest in 4 years. Principal cultural practices for established bogs are: (1) Draining the bogs in the spring, (2) controlling insects by using dusts and by flooding, (3) harvesting the attached berries by using wooden saw-edged scoops, (4) harvesting the fallen berries by flooding and floating off to the sides of the bog, (5) flood-

FIG. 111. Six kinds of small fruits. How many can you identify?

ing at the beginning of winter to protect the plants against low temperatures, (6) resanding if necessary (this is usually done every 3 or 4 years), and (7) draining the bog the following spring. Processed products are: cranberry sauce, cranberry juice, cranberry cocktail, and dehydrated cranberries. Figure 110 shows a general view of a 3-year-old cranberry bog in northeastern United States, and Figure 111 shows six kinds of small fruits —raspberry, blackberry, dewberry, strawberry, currant, and gooseberry. How many can you identify?

Questions

1. Differentiate between the root system of the strawberry and that of the grape.
2. What is the function of tendrils?
3. Male muscadine vines are non-productive yet essential for fruit production. Explain.
4. How does the stem of a grape differ externally from that of a raspberry?
5. How does a flower and fruit of the grape differ from those of the raspberry?
6. The principal centers of commercial production of strawberries are located in the Southeast and Pacific Coast regions. Give two reasons.
7. Although the strawberry is grown in all states of the United States, most commercial varieties have only narrow adaptation. Explain.
8. Currants and gooseberries are grown in the region of the Great Lakes and in the upper Pacific Coast. Give two reasons.
9. How do the roots of blueberry plants differ from roots of apple and peach trees?
10. What is the optimum soil pH range for blueberries?
11. How are cranberries harvested?

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Nut Fruits—Subtropical Fruits—Tung

Assignment 26

NUT FRUITS

The most important nut fruits of the world fall into two groups: (1) The evergreen tropical non-hardy and (2) the deciduous semi-hardy.

Evergreen Non-hardy

Principal evergreen non-hardy crops are coconut, Brazil nut, and cashew. These crops require very warm growing seasons and extremely mild non-growing or dormant seasons. At present coconuts are grown widely in the tropical regions of the world, Brazil nuts are confined largely to the valleys of the Amazon River and its tributaries, and cashew nuts are grown mainly in the tropics of India.

Deciduous Semi-hardy (Pecan, Walnut, Filbert)

PLANT CHARACTERISTICS

Root System. Although little experimental evidence is available on the nature and extent of the root system, authorities believe that the taproot forms a system of laterals which branch to form the absorbing system. In general, the degree of ramification is proportional to the size of the tops. For example, trees of the Persian walnut produce relatively small tops and a correspondingly sparse root system. On the other hand, trees of the black walnut and pecan develop a large top and a correspondingly well

developed and extensive root system. As with other tree crops, the depth of penetration depends largely on the looseness, drainage, and aeration of the subsoil.

Stems and Leaves. In general, the size and shape of the top varies with the kind of plant. For example, California walnut trees are small and round-headed; Persian walnut trees are medium-sized and round-headed; and pecan trees are tall and globular-headed. As with many other tree crops, the stem system consists of a trunk, primary, secondary, and tertiary scaffold branches and small branches or shoots. On the twigs and young branches the bark is smooth, and on the large branches and trunk it is rough and shaggy. The leaves are alternate and pinnately compound, and vary in number, size, and shape with the kind of crop. For example, pecan leaves have a large number of small, pointed leaflets, and walnut leaves have a small number of large, oval leaflets.

Flowers and Fruit. The deciduous nut crops are monoecious. In other words, the pistils and stamens are borne in separate flowers and both types of flowers are borne on the same tree. The pistillate inflorescence, called a cluster, develops from terminal buds on the past season's growth, and the staminate inflorescence, called a catkin, develops from buds at the base of one-year-old wood. Individual flowers are small and inconspicuous. The stamens produce large quantities of fine, fluffy pollen and the pistils present a comparatively large stigmatic surface. Air currents, the agent of pollen transfer, carry the pollen from the stamens to the stigmas.

Individual fruits are dry, indehiscent, one-seeded ovaries. According to the kind of plant, they vary in size from ½ to 1½ inches, in diameter and length from 1 to 2 inches, and in shape from round to oblong. The edible kernels are enclosed in a hard pericarp or ovary wall and contain from 65 to 70 per cent fat, from 10 to 16 per cent protein, and about 14 per cent carbohydrates. They are good sources of the B vitamins.

ECONOMIC IMPORTANCE AND DISTRIBUTION

In the United States walnuts are produced mostly in the Pacific Coast region with California the leading state, and pecans are produced mostly in the southern regions with Texas the leading state. Other important states are: Georgia, Alabama, Florida, and Mississippi.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal climatic factor is temperature. In common with other deciduous crops, the nut fruits have rather distinct

temperature requirements. In general, pecans require long, warm summers and short, mild winters. The long, warm, frost-free growing season is necessary for the full maturation of the nuts, and the short, mild winter is sufficiently cool to bring the buds out of the rest period. Thus, the crop is adapted to the warm summer, mild winter climates of the Southeast and Southwest rather than to the cool summer, cold winter climates of the Northeast and Midwest.

In contrast to pecans, walnuts and filberts require cool summers and moderately cold winters. Long cool summers are more favorable for the development of the nuts than long warm summers, and a rather long exposure to moderate cold is necessary to break the rest period. In fact, certain varieties of walnuts require as much cold as apples and others require only as much cold as peaches. In addition the trees are susceptible to foliage diseases in humid climates. Thus, walnuts and filberts are better adapted to the summer-dry climate of the Pacific Coast than to climates in the other regions.

Soils. In common with deciduous tree fruits deciduous nut crops require well-drained, well-aerated, and moderately fertile and fertile soil. According to observations at the California Experiment Station, adapted soils of the Imperial Valley should be well aerated to the 7- or 9-foot level, and those of the coastal areas should be well aerated to the 5-foot level. Within the pecan belt, highly productive trees are found growing on the well-drained, alluvial soils of the river valleys, particularly those of the Mississippi River and its southwest tributaries, and on the well-drained, fertile soils of the Piedmont and upper Coastal Plain regions. Infertile sands with a low water table and heavy clays with compact subsoils are unadapted. Filberts seem to be more tolerant of rather compact soils than walnuts or pecans.

Disposition of the Carbohydrates. As with other woody plants, the growth periods of deciduous nut crops are: (1) The formative, (2) the transitory, and (3) the fruiting. During the formative period the young trees are developing their root and stem systems—the trunk, primary, and secondary scaffold branches. Thus, all of the carbohydrates which are made are used for vegetative processes. During the transitory period, although the trees continue to develop their root and stem systems, they begin to produce flowers and fruits. Thus, not all of the carbohydrates are used for vegetative processes; some are needed for reproductive processes. During the fruiting period and for any one year, vegetative processes are dominant during the first part of the growing season and reproductive

processes are dominant during the latter part. Carbohydrate utilization is necessary for the development of the flowers, shoots, and young fruits, while carbohydrate accumulation is necessary for and is associated with the formation of flower buds and the maturation of the nuts.

PRINCIPAL CULTURAL PRACTICES

Planting Distances. The deciduous nut crops require relatively wide planting distances. With walnuts two systems are used: (1) The trees may be set 30 x 30 feet and later, usually when they are from 10 to 14 years old, three fourths of them are removed so that the remaining trees stand 60 x 60 feet, or (2) the young trees may be set 60 x 60 feet and intercropped until they become quite large. With pecans the young trees are set 60 x 60 feet, 60 x 70 feet, and 70 x 70 feet and intercropped during the first part of the life of the tree. With filberts the young trees are set 20 x 20 feet or 25 x 25 feet.

Soil Management and Nutrition. In general, the nut crops require the clean cultivation-cover crop system of soil management. Clean cultivation is practiced during the first part of the growing season to control weeds and cover crops are grown during the late fall, winter, and early spring. Satisfactory cover crops are: rye, or oats, or mixtures, or rye and vetch, or oats and vetch.

As with other fruit crops, the fertilizer program depends on the nature of the soil, the system of soil management, and the vigor and age of the trees. For example, walnut soils of the summer-dry climate of the Pacific Coast contain sufficient quantities of all nutrients except those supplying nitrate and zinc. In general, nitrogen carriers are used to meet the nitrogen requirements of the crop and pieces of galvanized iron, driven into the trunk and branches of the trees, are used to supply zinc. Pecan soils, particularly in the Southeast region, require applications of complete mixtures. As with other crops, the U.S. Department of Agriculture and agricultural experiment stations have developed fertilizer programs for local growers. For example, the U.S. Pecan Investigations Laboratory at Albany, Georgia, recommends mixtures containing 1–2–1 or 1–1½–1 ratios. In general, the amount that is applied depends on the age of the tree. Usually a two-year-old tree is given 2 pounds the first year, 3 pounds the next and an additional pound each year until the sixth year. For the next 10 years the amount is increased 2 pounds each year and for the next 30 years the amount is increased 2 to 3 pounds each year. For the remainder of the life of the tree 75 to 90 pounds are supplied each year.

Pollination. To understand the pollination requirements of walnuts, pecans, and filberts a working knowledge of dichogamy and self-incompatibility is required. Dichogamy involves the shedding of pollen before or after the pistils of the same variety are receptive. Self-incompatibility is concerned with the failure of the pollen tube to grow down the style. If, in the presence of a favorable environment, the pollen tubes of a given variety fail to grow down the style of that variety and effect fertilization, the variety is said to be self-incompatible. Investigations have shown that walnuts and pecans are dichogamous and that the filbert is partially self-incompatible. In the walnut, trees of certain varieties frequently shed all of their pollen before the pistils are receptive, and trees of other varieties sometimes shed most of their pollen after the pistils are receptive. To prevent any reduction in yields due to lack of adequate pollination, growers plant, at definite intervals, pollinator trees that shed pollen at the time the pistils of the commercial varieties are receptive. Some growers gather catkins of any species of walnut in mosquito netted bags, distribute the bags throughout the orchard and strike them with a pole to help spread the pollen into the wind.

With the pecan some varieties shed practically all of their pollen before the pistils are receptive; others shed most of their pollen after the pistils are receptive; and the same variety may shed pollen too soon in some seasons, about the right time in others, and too late in others. Thus, heredity and environmental factors are both involved. To insure adequate pollination of dichogamous varieties the pecan grower, like the walnut grower, plants pollinator trees at definite intervals throughout the pecan grove.

With the filbert most varieties are partially self-incompatible but all varieties are cross-compatible. Thus, growers of filberts interplant at least two varieties—the pollinator variety to shed pollen at the time the pistils of the commercial variety are receptive. In commercial orchards the accepted practice is to set a pollinator tree in every third space in every third row. Figure 112 shows two contiguous pecan orchards, near Lumberton, Mississippi. Note the large size of the trees, the wide spacings, and the cover crop system of soil management.

MARKETING

Harvesting and marketing operations of deciduous nut crops are quite similar. Pecan fruits are knocked from the trees, usually by bamboo poles, or are allowed to fall to the ground or on canvas spread under the trees.

FIG. 112. Pecan orchards in south Mississippi. (Courtesy, I. H. Bass, Lumberton, Mississippi.)

The fruits are then carried to the packing shed and "shucked." Walnut trees are shaken to make the fruits drop to the ground, or the fruits may be allowed to drop in the natural way. Filberts are allowed to drop to the ground in the natural way, carried to the drying sheds, and husked if necessary. After removing the hulls and washing (walnuts only) the nuts are dried, either naturally or artificially, to induce a dormant condition of the embryo and are graded according to size into several market classes to standardize the communities' output. They are then packed in large bags for shipping large quantities and in small bags and paper boxes for shipping small quantities, or for the retail trade. For long storage life a cool (35° to 40° F.) dry, odorproof environment is necessary.

Questions

1. How do the pecan and English walnut differ in the size of the tree?
2. The deciduous nut crops produce enormous quantities of pollen and the stigmatic surface is quite large. Explain.
3. What is dichogamy?
4. How does the grower overcome dichogamy in the walnut orchard? In the pecan orchard?
5. Many varieties of pecans require interplanting with pollinator varieties. Explain.
6. How does the grower overcome self-incompatibility of filberts?
7. Although pecan trees grow along the southern boundary of the Midwest, they rarely produce nuts. Explain.

8. Shading of the leaves of nut trees results in the development of poorly filled nuts of low oil content. Explain.
9. On heavily loaded filbert trees nuts in singles or in twos are usually better filled than those in threes or fours. Explain.
10. Water deficits during the period of kernel development are likely to result in poorly filled nuts. Explain.
11. A severe drought during July and August usually results in poorly filled pecan nuts. Explain.
12. Moderately vigorous vegetative growth favors maximum nut crop production. Explain.
13. How do the nutrient requirements of pecan trees grown in the Southeast differ from those of apple trees grown in the Northeast?
14. Nuts should not be stored with onions. Explain.

SUBTROPICAL FRUITS (Fig, Persimmon, Date, Avocado)

The Fig

Plant Characteristics. The fig is a deciduous bush* or tree. The root system is extensive. The laterals occupy the upper layer of soil and extend considerable distances, usually 50 feet or more. The branches or trunks are short. The bark is gray and the twigs have well-developed pith. The leaves are simple, alternate, three- to seven-lobed, thick, leathery, light green, and hairy (pubescent). The flowers are borne on the interior of a pear-shaped peduncle. This peduncle ripens and thus becomes the edible portion. When ripe, the flesh is coarse, pink, red purple, or violet and contains about 80 per cent water, 1.5 per cent protein, and 15 per cent sugar.

Fruiting Habit. There are two main types: (1) The Adriatic or common which grows in the Southeast and (2) the Smyrna which grows in California. The Adriatic fig is parthenocarpic; hence, it is seedless and does not require pollination. The Smyrna fig is non-parthenocarpic and hence requires pollination. The pollen used on Smyrna figs is secured from wild figs called caprifigs. A small wasp called blastopnaga carries the pollen.

The fig is prolific. In the United States two crops are usually borne and a third crop is not uncommon. The first main crop is borne on previous season's wood. The second and third crops are borne on current season's wood. As stated previously, figs are trained to the bush or tree form. Of these the bush form is preferred in the Southeast since the plants are often killed by subfreezing temperatures.

*The fig is trained to several main branches in southeast United States and is called a bush.

Importance and Uses. The fig is now widely distributed through tropical and subtropical countries. In the United States it is grown in the Southeast region and in California. In the Southeast many farm homes have one or two fig bushes growing in the yard. Figs are used in the fresh state or in various forms of preservation: canned, dried, preserved, candied, and pickled.

The Persimmon

Plant Characteristics. The persimmon is deciduous. There are two kinds: (1) Japanese and (2) native. With the Japanese the tree is upright spreading, has a round open top, and attains a height of 40 feet. With the native type the tree is upright, has a pointed top, and attains a height of 50 feet. In both types the roots develop a taproot and several laterals which penetrate the soil rather deeply; the leaves are simple, thick, large, leathery, and glossy green on the upper surface and light green on the lower surface; and the sex expression is dioecious. In other words there are male and female trees. Both sexes are borne in the axils of the leaves of the current season's wood. The female flowers are solitary, and the male flowers occur in clusters of three or four. The fruit is a round to oblong conicle, few-seeded or non-seeded, fleshy, juicy ovary. The skin is light orange or bright red. The flesh is yellow to cinnamon brown and soft and pasty in some varieties and stringy in others. A marked characteristic of the flesh is its astringency—due to tannin. When the fruits are immature, the walls of the cells which contain tannin are soluble in the mouth; hence, the tannin is released and the mouth puckers. When the fruits are mature, the walls of the cells containing tannin are insoluble; hence, the tannin is not released and the mouth does not pucker. Scientists have found that the astringence of the fruits can be removed by exposing them to ethylene. Ripe persimmons contain about 66 per cent water and 32 per cent sugars, and are a good source of vitamin C.

Fruiting Habit. The young trees are usually headed-back to about 36 inches when they are set and trained to four or five scaffold branches in much the same way as for peaches. The fruit is borne on the current season's wood and usually in alternate years. If annual crops are desired, some pruning is necessary. The Japanese prune off all shoots which have borne fruit in any particular year. The Chinese prune off the twigs bearing fruit at the harvest with long poles or sticks.

Importance and Uses. The Japanese persimmon originated in China. It has been grown in both China and Japan for hundreds of years. In the

United States the trees thrive well in the Southeast and Southwest and in California. The fruit is used mostly as a dessert.

The Date

Plant Characteristics. The date is a member of the palm family—monocotyledonous evergreen trees which produce leaves from terminal buds only. The date attains a height of 100 feet. Its wood is fibrous and spongy. The root system is adventitious, arises at the base of the stem, and consists of a large number of lateral roots which give rise to numerous absorbing roots. Roots penetrate to 20 feet or more. The leaves which arise from a terminal bud are large, 9 to 20 feet long, and parallel veined. The blade consists of 100 to 260 leaflets called pinnae. At the base of each pinnae several stiff hairs are borne. The date, like the persimmon, is dioecious. The inflorescence, both male and female, arises in the axils of the leaves, is large, much branched, and contains thousands of individual flowers. Scientists have found that the pollen has a marked effect on the size, shape, and time of maturity of the fruit. After pollination, two of the three carpels in each female flower drop and the remaining carpel grows to maturity. If pollination does not take place, all three carpels or fruits remain on the tree, but do not develop into high quality fruits. Hence, pollination of all three carpels is necessary for the proper development of the fruit. The fruit is a one-seeded, oblong berry, the skin color varies from yellow to purplish black, and the flesh is dry, semi-dry, or moist. The water content varies from 22 to 51 per cent and the sugar content varies from 71 to 86 per cent. Thus, dates are very nutritious.

Fruiting Habit. Since the main axis grows like corn, the only pruning necessary is removing old leaves as the terminal bud elongates. Pruning is done by cutting the leaf petiole about 8 to 12 inches from the trunk at the rate of 12 to 20 leaves per year and by removing all suckers from the base of the trees during the early period of growth. In Arizona, growers usually remove the shoots between April 15 and July 1. In general, growers are very careful to avoid wounding of the trunk. Wounds of this type of tree, a monocot, fail to heal. The date is essentially a high temperature plant. Temperatures as low as 15° to 18° F. severely injure the leaves, but apparently fail to harm the terminal bud.

Uses. The date, believed to be a native of northern Africa or Arabia, has been in cultivation for over 4000 years. It is grown in arid tropical and subtropical regions where sufficient water is available for the trees. In the United States commercial crops are grown in the Coachella Valley

of southern California and Arizona. In this country the fruit is used only as dessert either in the fresh or dry state. In many other countries (North Africa) both the fruits and trees are used. The fruit constitutes the chief article of diet of the Arabian people; the sap is fermented for the making of alcoholic liquors and vinegar; the trunk is made into fence posts; and the leaves are made into ropes, baskets, and crates.

The Avocado

Plant Characteristics. The avocado is a dicotyledonous evergreen. Trees attain a height of 60 feet. They differ in habit of growth. Some are low and spreading; others are tall and upright. The roots are shallowly situated and hence occupy the upper portion of the soil. The leaves are thick, leathery, and bright green. They vary in shape and in length—3 to 16 inches. The flowers, which are borne in clusters at the tips of branches, are smooth and possess two series of petal-like structures called perianth lobes. Scientists have discovered a remarkable synchronization in the opening and closing of the flowers and in pollen shedding and pistil receptivity. Certain varieties open their flowers in the morning, at which time the pistil is receptive, close again in midday, and open again the following afternoon, at which time the pollen is shed. Other varieties open their flowers in midafternoon, at which time the pistil is receptive, and close again in late afternoon and open again the following morning or morning of the second day, at which time the pollen is shed. Thus, when the pistils of the one variety are receptive, the pollen of the other variety is shedding; conversely, when the pistils of the other variety are receptive, the pollen of the one is shedding. In this way, the various varieties are successfully pollinated. Within any variety marked changes in the weather will markedly change this normal schedule.

The fruit is a one-seeded, fleshy berry, and varies from round to oval to pyriform or necked. Both seed and flesh vary greatly in size. The skin is yellowish green, purplish green to purplish blue, thin and membraneous in some varieties; and thick and woody in others. The flesh, which separates readily from the skin, is light green to yellow and has a buttery consistency. It contains from 10 to 20 per cent fat and about 80 per cent water and is a good source of vitamin C. Thus, the fruit is very nutritious.

Importance and Uses. The avocado is a native of tropical America. In the United States it is grown in southern Florida and in southern California only. Avocados are used as salads, in ice cream making, as a base for milk shakes, and in the manufacture of mayonnaise. There are three

horticultural races: (1) West Indian, (2) Guatemalan, and (3) Mexican. The West Indian is the least resistant to cold and is grown principally in Florida; the Guatemalan is moderately resistant to cold and is grown mostly in California; and the Mexican is the most resistant to cold and is grown in Florida and California.

TUNG

Tung trees are grown for their fruits which contain seed which in turn contain large quantities of oil. This oil has excellent drying properties. Thus, it is used extensively in the making of paints, varnish, linoleum, oilcloth, and printer's ink.

Plant Characteristics. The trees are deciduous and monoecious. They attain a height of 12 to 20 feet and have a tendency to produce whorled branches. The leaves are comparatively large, simple, heart-shaped or three-lobed, and dark green. The inflorescence is a cluster. This cluster arises on the terminals of twigs of the past season's growth and contains from one to three pistillate flowers and a relatively large number of staminate flowers. The individual flowers are showy, open just before the unfolding of the leaves, and are white or tinged with pink in the throat. Since no pollination problems have been reported, dichogamy or incompatibility are apparently not present. The mature fruit is round or globular, 2 to 3 inches in transverse diameter, has a dark brown outer cover and contains from four to seven relatively large, firm, brown seeds. As previously stated, the seeds contain comparatively large quantities of oil. Figure 113 is a close-up of a tree in the Wade orchard, Lucedale, Mississippi. Note the leaf and fruit characters, and age of wood on which the fruit is borne.

Economic Importance and Distribution. Tung is a native of central China. The trees were first grown in the United States in 1904. Since that time, ecologic studies and trial plantings in the warm sections of the United States showed that the trees thrive best in a belt from 50 to 100 miles wide extending from northern Florida westward to southern Louisiana and eastern Texas. At present Mississippi leads in commercial plantings with over 10 million trees, followed by Florida, Louisiana, Alabama, and Georgia in the order named.

Growth and Development. From the standpoint of temperature, tung requires a long, warm, frost-free growing season and a short, comparatively mild non-growing season. The long, warm growing season temperature permits maximum photosynthesis, which in turn is manifested by maximum

Fig. 113. Close-up of tung tree. Note that the fruit is borne on the young wood. (Courtesy, G. F. Potter, U.S. Department of Agriculture.)

growth of the tree and yields of the fruit. The short, mild non-growing season temperature is necessary to bring the trees out of the rest period. From the standpoint of the water supply, the abundant rain during the spring and summer promotes rapid vegetative growth and the relatively light rains during the fall favor carbohydrate accumulation which is necessary for oil formation. From the standpoint of soil, slightly acid sandy loams underlaid with a uniformly brown or reddish sandy clay are considered best. Ruston, Orangeburg, Norfolk sandy loams, and closely related types are well adapted to tung production.

Principal Cultural Practices. Cultural practices are in accordance with the nature of the climate and needs of the soil in the tung belt and with the nutritional needs of the trees. In general, satisfactory yields require: (1) Selecting well, air-drained sites, (2) planting trees of recommended

FIG. 114. Row view of tung orchard during period of clean cultivation. (Courtesy, G. F. Potter, U.S. Department of Agriculture.)

strains on wide-based terraces in January, February, and early March (usually the trees are set 20 feet apart in rows 35 feet apart), (3) training the young tree to the open center form, (4) applying nutrients to promote the desirable amount of shoot growth, number of flower buds, and fruits per year (usually ½ to 1 pound of a complete mixture per year of age of tree is applied when growth starts in the spring), (5) using the controlled-cover crop system of soil management with the land free from the cover crop in March, April, and May, and (6) allowing the fruits to drop from the trees and to remain on the land under the trees from 4 to 6 weeks and placing the fruit in burlap sacks and hanging the sacks in the trees for additional drying, or transporting the fruit to the drying shed. When the fruits have 12 per cent moisture or less, they are ready for the crushing mill. Figure 114 shows a down-the-row view of a nine-year-old tung orchard near Alford, Florida. The soil is sandy for a depth of 4 to 5 feet beneath which is a friable sandy clay.

Questions

1. The fig is difficult to graft and pruning wounds often fail to heal. Explain.
2. The Adriatic fig is not propagated by seed. Explain.

3. Show how the pruning of figs is similar to that of the peach.
4. Immature fruit of the Japanese persimmon is astringent; mature fruit is not astringent. Explain.
5. Compare pruning of the Japanese persimmon with that of the peach.
6. Describe a date tree.
7. A wound in a date tree does not heal like a wound in an apple tree. Explain.
8. The three races of avocados differ in the degree of low temperature they can withstand. Which race will do best in Florida? In California?
9. Describe the opening and closing of avocado flowers.
10. Although tung is monoecious, considerable self-pollination takes place. Explain.
11. Transplanting tung trees in late March and April usually results in poor stands and unsatisfactory growth. Explain.
12. Tung trees require clean cultivation during March, April, and May. Give two reasons.
13. In your opinion would summer or winter cover crops be the more satisfactory for tung production?
14. Given two growing seasons. Season A has a dry April and May and a wet September and October; season B has a wet April and May and a comparatively dry September and October. In your opinion which season would produce fruits with the highest percentage of oil? Give reasons.

19

Vegetable Crops Grown for Their Stems and/or Leaves

Assignment 27

THE PERENNIALS

Asparagus

PLANT CHARACTERISTICS

Root System. Asparagus has two kinds of roots: (1) Fleshy (storage) and (2) absorbing. The fleshy roots are about the size of an ordinary lead pencil. In general, they grow in a lateral direction from 8 to 14 inches per year for about 3 to 4 years. Their principal storage constituent is sucrose. The absorbing roots arise from the young portions of the storage roots. Thus, the roots of mature asparagus plants have a spread of 3 to 5 feet or more.

Stems and Leaves. Asparagus has two kinds of stems also: (1) Underground (rhizomes) and (2) aerial (spears and stalks). The rhizomes are short, thick, and stubby. They grow upward at the rate of about 2 inches per year and form buds which develop into the aerial stems.

The stems which are cut for market are called spears, and those which grow after the cutting season are called stalks. In general, spears are cut when they are 6 to 8 inches long and for a period of 6 to 8 weeks. The leaves are small, triangular, scale-like, vestigial structures. They do not manufacture food. The stems which contain chlorophyll are the real food-

manufacturing organs. Thus, asparagus stems have been modified for the manufacture of the carbohydrates.

Flowers, Fruit, and Seed. Asparagus is dioecious. Investigations have shown that male and female plants differ in earliness, yield, and size of spears. In general, male plants produce spears smaller in size, greater in quantity, and earlier in the spring than female plants. The flowers of both sexes are small, numerous, and axillary. Various species of bees carry the pollen.

The fruit is a small, spherical berry; green when immature and red when ripe. The seed are relatively large, black coated, and angular. The principal reserve carbohydrate is hemicellulose. Investigations have shown that germination is facilitated by soaking the seed in warm water at 84° F. for 84 hours. The water is changed frequently to supply the necessary oxygen.

ECONOMIC IMPORTANCE

Asparagus is used fresh and canned. It is grown in many home gardens particularly in the northern sections of the United States. Since extremely hot summers and mild winters are unfavorable for the development of a large number of spears, asparagus is not grown in the region of the Gulf Coast. The commercial asparagus industries in this country have developed since 1900. The principal districts are located in the Sacramento and Imperial Valleys of California, in the upper Coastal Plain section of New Jersey, South Carolina, and in Illinois. Figure 115 shows a field of asparagus in full fern in the Sacramento district of California.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal climatic factors are temperature and moisture. As stated previously, asparagus thrives well in all regions

FIG. 115. A large field of asparagus in full fern in the Delta-Sacramento district of California. (Courtesy, G. C. Hanna, University of California.)

of the country except along the Gulf Coast. In this area there is a continual development of stalks throughout the latter part of the growing season. This excessive stalk production utilizes sucrose which in turn limits the amount for storage and subsequent spear growth. As a result, the spears are small in size and few in number and yields are low. However, high growing season temperatures alone do not inhibit profitable spear production. In the Imperial Valley of California the excessive heat of summer inhibits stalk growth but applications of irrigation water keep the tops green. In late summer irrigation is discontinued. This stops stalk growth and facilitates the storage of sucrose in the roots.

Soils. Ideal soils for asparagus are deep, well drained, friable, fertile, and slightly acid. In general, soils of a peat-sediment mixture, mucks, and loams are used. These soils, being loose and friable, allow the point of the spear to remain straight. Clay soils do not drain readily and produce a large percentage of crooked spears.

Disposition of the Carbohydrates. As previously stated, spears are harvested at the beginning of the season, and stalks are allowed to grow after the harvest. Thus, carbohydrate depletion, utilization, and accumulation occur in succession.

	spear production		stalk growth		manufacture of sucrose	
A	depletion	B	utilization	C	accumulation	D

In general, the growing season for asparagus varies from 24 to 32 weeks depending on the region of the country where asparagus is grown. Thus, line AD can be used to represent the length of the growing season; line AB the length of the harvesting season; and line BC the period of stalk growth and development. The periods represented by line AB and BC show that carbohydrate depletion is taking place, since from AB spears are removed and in BC most of the stalks are produced; and the period represented by line CD shows that carbohydrate accumulation is taking place, since stalk growth has practically ceased at point C.

PRINCIPAL CULTURAL PRACTICES

The life of asparagus plants may be divided into three stages: (1) The seedling, (2) the preproductive, and (3) the productive. The *seedling* stage consists of growing the young plants in a nursery for 1 or 2 years. In general, seed is planted during the first month of the growing season, preferably in well-drained, slightly acid, sandy loams and in rows 2 or 3 feet apart. To reduce competition between the seedlings in the nursery

row, the seed are dropped, either by hand or by machine, singly, 1 to 3 inches apart.

The *preproductive* stage consists of the first 2 years in the permanent bed. In the Southeast and in California the seedlings are set in the bed in late winter and early spring, and in the Midwest and Northeast they are set in the spring. In general, individual crowns are set 18 or 24 inches apart and 8 to 10 inches deep in furrows 5, 6, 7, or 8 feet apart and covered with from 1 to 2 inches of soil. As the tops grow the soil is cultivated toward the plants until the furrow is filled.

The *productive* stage consists of the development of spears and the development of stalks. For any one season the plants produce spears for a period of from 6 to 8 weeks after which the spears are not cut, and are allowed to grow and develop for the remainder of the season. During the growing season the principal practices in consecutive order are: (1) Applying a complete fertilizer and disking the rows just before the cutting season begins, (2) cutting, grading, and marketing the spears, (3) at the end of the cutting season applying fertilizer and furrowing the rows, (4) allowing the stalks to grow, and (5) controlling weeds and insects. For long distance markets the spears are packed in bunches, placed in pyramidal crates, and shipped under refrigeration.

Questions

1. One-year-old asparagus roots recover more rapidly from the check in growth incident to transplanting than two-year-old roots. Explain.
2. The crowns are set from 8 to 10 inches deep. Explain.
3. Before asparagus is cut the plant is allowed to grow 2 to 3 years. Explain.
4. The cutting of the spears usually extends for 6 to 8 weeks. Why is cutting stopped at the end of this period?
5. In which region of the country should cutting the spears extend the longer—the northern region or the upper part of the southern region? Give reasons for your answer.
6. What do you suppose is the relation of size of spear to the carbohydrate content of the storage roots? Give reasons for your answer.
7. Would you expect the spears to maintain their diameter with each successive cutting or to decrease in diameter? Explain.
8. The sugars in asparagus roots gradually decrease throughout the cutting season. They rapidly decrease during the period of stalk growth. Explain.
9. What are the indications that an asparagus plant has been cut too long in any given season? Give reasons for your answer.

10. The sugars in asparagus roots markedly increase after most of the stalks have fully developed. Explain.
11. When would you apply nitrogen to asparagus: (1) At the beginning of the cutting season? (2) at the end of the cutting season? or (3) at both periods? Give reasons.
12. A severe infestation of asparagus beetles during the latter part of the growing season will result in low yields the following year; infestation at the beginning will not. Explain.
13. Given two asparagus plantations at the end of the growing season. In plantation A the stalks are cut while they are still green. In plantation B the stalks are cut after they become dry. Which plantation has the greater carbohydrate supply? Give reasons.
14. The life of the average commercial planting is about 15 years, yet some home garden plantings remain productive for 20 to 30 years. Can you think of any reasons for this?

Rhubarb

Plant Characteristics. The root system of rhubarb consists of absorbing roots and is extensive. The stems are of two kinds: (1) Rhizomes and (2) aerial. The rhizomes are fleshy and woody and bear buds at the crown. The aerial stems attain a height of 3 to 4 feet and produce a spike of large numbers of small greenish white, perfect flowers. The leaves arise in the form of a rosette from the buds on the crown. The blade is simple and large. The petiole or leaf stalk is the edible portion and is long, fleshy, and well developed. The color of the petiole varies from green, due to chlorophyll, to dark red, due to anthocyanin.

Economic Importance. Rhubarb is grown in home gardens, commercial gardens, and for forcing. Home garden and market garden production are quite popular in northern United States, Canada, and the British Isles and forcing for winter market takes place in the vicinity of Detroit, Michigan; Boston, Massachusetts; and Chicago, Illinois.

Rhubarb is adapted to comparatively cold regions. It thrives well in regions north of the Potomac and Ohio Rivers and in the mountains of Virginia and North Carolina. Well-drained, moderately to slightly acid, fertile, sandy loams and silt loams, and slightly acid, highly decomposed mucks are better than poorly drained and infertile soils.

Like asparagus the harvesting period of rhubarb usually consists of 6 to 8 weeks only, and the leaves are allowed to grow during the remainder of the growing season. Hence, like asparagus, carbohydrate depletion, utilization, and storage occur in succession.

Growing the Crop. In home and commercial gardens rhubarb is propagated by division of the rhizomes. The rhizomes of comparatively

large plants are divided into several pieces in such a way that each piece has at least one vigorous bud. Division takes place during the non-growing season and the pieces are planted 3 to 4 inches deep, 2 to 3 feet apart in rows 4, 5, or 6 feet apart. Between planting and harvesting, a period of 1 to 2 years is necessary for the development of a large storage structure. In regions characterized by short-growing seasons, this period consists of 2 years. In regions of long-growing seasons, petioles may be harvested for a short time during the second year.

When forced on a commercial scale, the plants are grown in the field for 2 years and after the tops die down in the fall, the rhizomes are dug or plowed out and allowed to freeze. The exposure to subfreezing temperatures breaks the rest period. In this way the internal conditions within the crown become favorable for rapid growth of the fleshy petioles. After exposure to the subfreezing temperature, the crowns are placed side by side in forcing houses, subjected to air temperatures of 50° to 60° F. and when the buds begin to grow they are covered with a 2- to 3-inch layer of soil which is kept moist by applications of water. This layer of soil prevents a rapid evaporation of water from the rhizomes and supplies water for the development of the petioles. The forcing houses are long, low wooden sheds with the roof covered with straw, sawdust, or incinerated garbage for insulation. They are kept dark except when electric lights are needed while tending the heating stove or while harvesting. Because of the lack of light the leaf blades are very small, the petioles become etiolated and anthocyanin with very little chlorophyll develops.

Marketing operations consist of: (1) Pulling the petioles when they are from 15 to 18 inches long, (2) grading the petioles according to their diameter, (3) packing the petioles in 5-pound lots in paper cartons, and (4) packing the cartons in groups of ten in pasteboard boxes. Special varieties for forcing have been developed.

Globe Artichoke

Plant Characteristics. The root system is extensive. The stem consists of two kinds: (1) Rhizome and (2) aerial. The aerial stems are relatively long and bear long, deeply lobed, thistle-like leaves. The flower head, the edible part, terminates the stem and consists of a mass of fleshy, imbricated bracts which when young are tender and edible. They contain inulin—a form of starch.

Climatic Requirements. The Globe artichoke is adapted to regions characterized by mild temperatures. Low temperatures, those below freez-

ing, injure the leaves and stems, and high temperatures, those above the optimum, induce opening of the flower buds and reduce tenderness and quality. For commercial markets the crop is grown along the coast in Monterey, Santa Cruz, and San Mateo counties of California.

Growing the Crop. The Globe artichoke is propagated by offshoots from the rhizome. In California the rows are usually 8 feet apart and the plants 6 feet apart in the row. Clean cultivation is given as needed.

Like asparagus and rhubarb the harvesting period is from 6 to 8 weeks, and the tops are allowed to grow during the remainder of the growing season. Consequently, carbohydrate depletion, utilization, and storage proceed successively.

Questions

1. In northern United States harvesting of rhubarb does not take place until the plants are 2 years old. Explain.
2. The disposition of the carbohydrates in rhubarb is quite similar to that in asparagus. Explain.
3. Harvesting longer than 6 or 8 weeks is likely to exhaust thoroughly the carbohydrate supply in the rhizomes and thus excessively devitalize the plant. Explain.
4. In your opinion, when should available nitrogen be applied, at the beginning, or at the end of the cutting season, or both? Give reasons.
5. In commercial plantations seed stalks are usually cut off when they begin to develop. Explain.
6. In what ways is the growing of rhubarb similar to the growing of asparagus; in what ways different?
7. Rhubarb grows satisfactorily in the mountains of Virginia and North Carolina; it does not thrive in the Gulf Coast section of the United States. Explain.
8. In what respects is the growing of the Globe artichoke similar to that of asparagus and rhubarb; in what respects different?

THE BIENNIALS

The Cabbage Crops

The cabbage crops, sometimes called the cole crops, consist of cabbage, Brussels sprouts, cauliflower, collards, kale, and kohlrabi. During the first year the plants develop a distinct storage organ, and during the second year they develop flowering stems, flowers, fruit, and seed. Plants of the cabbage crops are closely related and have characteristics in common and characteristics in distinction.

COMMON PLANT CHARACTERISTICS

Root System. The plants develop a much branched, highly ramified root system. For example, investigations have shown that the roots of half-grown cabbage plants extended laterally for a distance of from 2 to 4 feet. These roots were much branched especially in the upper 4 inches of soil. Consequently, deep cultivation of the cabbage crops during the late stages of growth is likely to cut the feeding roots just beneath the surface.

Stems and Leaves. The vegetative stems are comparatively short, and the leaves are simple, large, well developed, and fleshy. Those that consist of the storage organ contain large quantities of starch which gradually change to sugar. The flowering stems arise from the axils of the leaves of the storage organ and are from 2 to 4 feet high.

Flowers, Fruits, and Seed. The inflorescence is a terminal raceme. Individual flowers are perfect and regular with four sepals, four white or light yellow petals, six stamens, and a two-celled pistil. The flowers are mostly insect-pollinated and varieties within each group cross readily. The fruit is a long slender pod called a silique. The seed are quite similar in appearance and germinate readily under favorable conditions.

CABBAGE

Cabbage develops a short stem and a *large terminal bud called the head.* The head is the storage organ and the part used for human consumption. It varies greatly in size, shape, texture, and color according to the variety.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal climatic factor is temperature. Cabbage is primarily a cool-season crop. In general, the crop thrives best and produces the best heads at temperatures from 50° to 70° F. Thus, profitable crops can be grown in the Southeast and Southwest during the winter and early spring, and in the Northeast and Midwest during the summer. Climates influenced by large bodies of water are particularly favorable for the growing of cabbage. In both the southern and northern regions of the United States, many commercial districts are located near large bodies of water. In the South, the Atlantic Ocean and the Gulf of Mexico help keep the temperatures from becoming dangerously low in the fall and winter; and in the North, the Great Lakes help keep the temperatures from becoming excessively high in the summer.

Soils. Cabbage is grown on a wide variety of soils. In general, the crop

for early market and long distance shipment is grown on well-drained sandy loams; and the crop for storage, sauerkraut manufacture, or pickling is grown on well-drained silt loams and clay loams. In southern Wisconsin and upstate New York, most of the storage crop is grown on dairy farms in a general crop rotation. In both the early and late crop industries adapted soils are moderately to slightly acid, and if fusarium wilt, a serious fungus disease, is present, resistant varieties are grown.

Disposition of the Carbohydrates. As stated previously, cabbage is grown for the enlarged bud. As with other crop plants in which storage is required, the first period of growth is given over to the development of roots, leaves, and stems, and the latter period is given over to the development of the storage organ. During the early period of growth cabbage develops a large number of green leaves, and sometime later the young leaves form a compact mass which develops from the inside and contains no chlorophyll. These leaves are quite fleshy and are full of starches and sugars.* Hence, utilization is dominant over accumulation during the early stages of growth. As the plant produces its required number of food-manufacturing leaves, accumulation gradually becomes dominant thus permitting carbohydrate storage. Growing conditions, therefore, during the first period should be such as to favor the production of stems and leaves, and during the latter period they should be such as to favor the development of the storage organ and the accumulation of carbohydrates. Line AB, which represents a growing period of 70 to 125 days depending on the variety and the season, illustrates the period of utilization and accumulation.

A	growth of stem, leaves and roots	⟶	development of storage organ	B
	utilization dominant	⟶	accumulation dominant	

ECONOMIC IMPORTANCE AND DISTRIBUTION

Of the cabbage tribe, cabbage is the most widely grown and the most commonly known. This crop was grown extensively in ancient times, and at present is an important crop in the temperate regions of the earth. In the United States it is grown in home gardens for both immediate use and for storage; in many winter garden areas of the Southeast and Southwest for long distance shipment in early spring; in many market garden areas

*This storage of carbohydrates has not been done primarily for the use of man but primarily for the development of flowers. Man only adapts this behavior for his own use.

for local markets; and in the Midwest and Northeast for storage, sauerkraut manufacture, and pickling. Shipments from the winter garden areas of the Southeast and the Southwest usually begin in December and end in July, and shipments from the Midwest and Northeast usually begin in August and continue to December and January. The student will note that the southern regions ship cabbage north in the spring and early summer, and that the northern regions ship cabbage south in the fall and winter. In this way every city and town in the country is supplied throughout the year with this important vegetable.

Types. Distinct types of cabbage have been developed to meet the many present day requirements: for immediate consumption in local and long distance markets, for immediate consumption and/or sauerkraut manufacture, and for storage. Thus, three varietal groups are recognized: (1) The small-headed, early; (2) the large-headed, midseason; and (3) the large-headed, late and storage. For example, varieties of the first group are grown in the winter garden areas of the Southeast and Southwest, since they must successfully withstand long periods of cool weather and produce small, quick-maturing heads. On the other hand, varieties of the third group are grown in the Northeast and Midwest, since they must produce large heads which keep well in storage.

PRINCIPAL CULTURAL PRACTICES

Growing the Crop. Three distinct methods are used to start cabbage crops: (1) Planting seed directly in the field, (2) planting seed in open field beds, and (3) planting seed in greenhouses, hotbeds, or cold frames. Planting seed directly in the field is practiced in northern regions and in South Carolina, Louisiana, and Texas. This practice is adapted for planting during the summer when recovery from the check in growth incident to transplanting is rather slow. When the plants become established thinning is necessary. Planting seed in open field beds is the usual method in many winter garden areas along the Atlantic and Gulf Coast. The land is prepared in low flat beds, usually from 5 to 6 feet wide, and the seed is planted in rows from 4 to 6 inches apart. Planting seed in plant growing structures is practiced in certain producing districts in Mississippi and in the North for starting the early crop.

The transplants are set by hand or by machine. In general, the distance between the rows depends largely on the variety and the fertility of the soil. The early-maturing, small-headed varieties are usually set from 12 to 18 inches apart in rows 3, 3½, or 4 feet apart; and the late-maturing large-

Fig. 116. A field of cabbage in eastern United States. (Courtesy, V. R. Boswell, U.S. Department of Agriculture.)

headed sorts are set from 24 to 30 inches apart in 3-, 3½-, or 4-foot rows. Since cabbage develops an extensive, shallowly situated root system, cultivation is practiced only when the plants are small or when the land forms crusts after heavy rains. Figure 116 shows a field of half-grown cabbage. Note that the land is free from weeds.

Harvesting and Marketing. The heads are harvested as soon as they are firm and have attained the right size. For the early market from two to four jacket leaves are left attached to protect the heads during handling and shipping. Most of the cabbage grown in the winter garden areas is shipped in crates, and most of the crop for storage is shipped in bulk.

Brussels Sprouts

Brussels sprouts develop an elongated, unbranched erect stem, and *a large number of small lateral vegetative buds.* In reality these buds are small heads and comprise the storage organ. The food-manufacturing leaves are comparatively large and about as broad as they are long.

Culture. Market gardeners and home gardeners raise Brussels sprouts quite extensively in northern France, Belgium, Holland, and the British Isles. In the United States it is not widely grown in home gardens and commercial areas are confined to specialized districts. These districts indicate the temperature requirements for Brussels sprouts. They are located in Long Island, New York; and in the Moon Bay region just below San Francisco, California. Note that those areas are adjacent to large bodies of water.

Cauliflower and Broccoli

Cauliflower and broccoli produce *an undeveloped flower head* or curd.* When the head is ready to cut, the flower primordia are not present and appear later. The leaves of cauliflower and broccoli are generally longer than those of cabbage.

Culture. Of the members of the cabbage crops, cauliflower and broccoli are the most sensitive to temperatures below and above their optimum range. In fact, uniformly cool temperatures are required for successful cauliflower and broccoli production. In general, temperatures below the optimum range during the early stages of growth induce premature heading, and extremely high temperatures during the period of curd formation induce a "riced" condition and leafiness of the heads. Low humidity and high winds are injurious also. In other words, cauliflower and broccoli require cool, moist conditions. For this reason cauliflower, like Brussels sprouts, is grown in specialized regions. Chief producing areas are located on Long Island, New York, in certain districts in upstate New York, and in California and Oregon. In general, the plants are grown, transplanted, fertilized, cultivated, and harvested in much the same way as cabbage.

Green Broccoli

Green broccoli develops *a comparatively large number of small, green undeveloped flower heads.* Individual heads are formed both terminally and laterally and an individual plant produces shoots for several weeks. The climatic, soil, and cultural requirements are similar to those for cauliflower and broccoli. Commercial areas exist near Norfolk, Virginia, and in California.

Collards

Collards develop *large fleshy leaves which are used for greens.* The plants are very hardy to cool temperatures and resistant to high temperatures. Hence, collards are better adapted to the high summer temperatures of the southern regions than are other members of the cabbage crops. Figure 117 shows a field of collards in eastern Virginia.

Kale

Like collards, kale develops *large, green leaves which are used as greens.* Kale varieties vary in plant height (dwarf and tall); shade of green of the

*Horticulturists are not fully agreed on the true nature of the cauliflower head.

FIG. 117. A field of collards in eastern Virginia. (Courtesy, M. M. Parker, Virginia Truck Experiment Station.)

foliage (grass green and gray green); and indentation of the leaves (indented and smooth). In general, kale plants can withstand fairly low temperatures but are sensitive to high temperatures. Thus, kale thrives best in

FIG. 118. A field of kale in eastern Virginia. (Courtesy, M. M. Parker, Virginia Truck Experiment Station.)

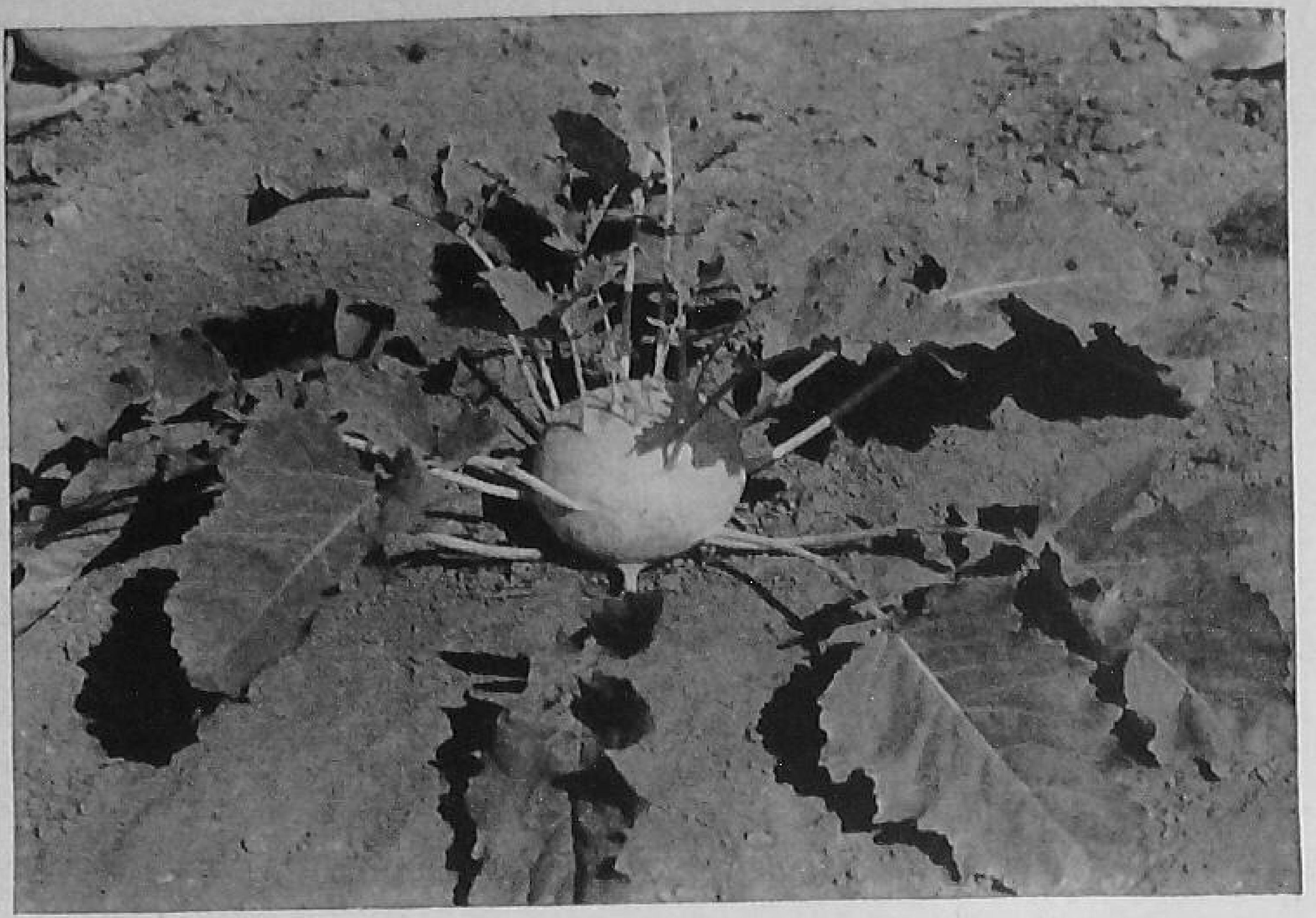


FIG. 119. A plant of kohlrabi. Note that the carbohydrates are stored in the stem. (Courtesy, Associated Seed Growers, New Haven, Connecticut.)

comparatively cool weather. The most important commercial district is located near Norfolk, Virginia (see Figure 118).

KOHLRABI

Kohlrabi develops *a short, fleshy turnip-like stem.* The enlarged stem is the storage organ and contains starches and sugars. The leaves are comparatively small and oval. Kohlrabi thrives well in comparatively cool weather only. In general, the seed is planted in rows 1½, 2, or 3 feet apart and the seedlings are thinned to stand 8 inches apart in the row. Kohlrabi is harvested when the fleshy stem is from 2 to 3 inches in diameter. It is grown in home and market gardens only. Note the storage stem and the position of the leaves of the plant in Figure 119.

Questions

1. Distinguish between cabbage, cauliflower, broccoli, Brussels sprouts, collards, kale, and kohlrabi.
2. Cabbage is grown in late fall, winter, and early spring in the southern regions; in summer and fall in the northern regions. Explain.
3. In the South quick-maturing, small-headed varieties are raised. In the North slow-maturing, large-headed varieties are raised. Explain.

4. In the South well-drained sandy loams and heavy applications of commercial fertilizers are used. In the North well-drained silt and clay loams and moderate applications of commercial fertilizers are used. Explain.
5. In the South young plants are frequently exposed to long periods of low temperatures. Frequently many plants go to seed without forming a head. Explain.
6. Is the biennial habit in cabbage a fixed hereditary characteristic? Cite instances where cabbage is grown commercially and frequently becomes an annual.
7. List those members of the cabbage crops which can be most easily grown; those which are not easily grown.
8. Brussels sprouts are grown extensively in the British Isles and not extensively in the United States. Explain.
9. In the South the collard is quite popular in home gardens. Explain.

Celery

PLANT CHARACTERISTICS

Root System. The root system of celery is non-extensive. The taproot is destroyed by necessary transplanting and, as a result, a moderate number of laterals develop. Studies of the root system show that the lateral roots of full-grown plants extend for a comparatively short distance only. For example, at Cornell University most of the roots of plants growing in sandy loam were found within a radius of 6 inches from the base of the plants, and most of these roots were within 2 to 3 inches from the surface. The comparatively sparse root system explains why the plants can be set close together—from 6 to 8 inches; why celery cannot readily compete with weeds; and why the topsoil should be abundantly supplied with water and nutrients.

Stems and Leaves. During the first year the plants produce a short, stubby stem usually from 3 to 6 inches long, and a large number of thick petioled, pinnately compound leaves. The petioles are conspicuously ribbed, very broad at the base, and contain comparatively large quantities of starch and related substances. During the second year the much-branched flowering stem arises from the axils of the fleshy petioles and on maturity attains a height of 2 to 3 feet.

Flowers and Fruit. The inflorescence is an umbel. Individual flowers are small, perfect, and are mostly self-pollinated. Mature fruit, called "seed," are small and dry and have corky ribs. For satisfactory germination the "seed" require shallow planting and a uniform supply of moisture.

ECONOMIC IMPORTANCE AND DISTRIBUTION

Prior to World War I, the fleshy petioles of celery were considered a luxury, now they are considered a necessity. Important commercial districts are: the Delta and Los Angeles in California, the Kalamazoo and Muskegon in the Lower Peninsula of Michigan, the Williamson of New York, and the Sanford and Lake Okeechobee of Florida. Modern varieties possess dark green petioles which when blanched become golden-yellow.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal environmental factors are temperature and water supply. Celery is primarily a cool-season crop. It is grown, therefore, as a summer crop in northern regions, as a winter crop in southern regions and as a spring crop in the intermediate region. California, because of its many climates, grows the crop throughout the entire year—in the Imperial Valley in the winter and in the more northern sections of the state in the spring and summer. In Florida the crop is grown in late winter and early spring, and in New York and Michigan it is grown in late spring, summer, and fall. Thus, the many towns and cities of the United States are supplied with celery throughout the year.

Soils. Celery grows best on deep, slightly acid mucks and on slightly acid, fertile mineral soils high in organic matter. In California, New York, and Michigan it is grown mostly on well-drained, slightly acid mucks; and in

FIG. 120. The establishment of a celery field in central Florida. Note the 12-row transplanter. (Courtesy, J. C. Hoffman, U.S. Department of Agriculture.)

New Jersey and Florida on deep fertile, slightly acid loams and mucks. Note the large muck land field and the 12-row transplanter in Figure 120.

Because of its non-extensive root system, celery requires a continuous supply of water. For this reason mucks which have a controlled water table are adapted to celery. On mineral soils irrigation is usually necessary.

Disposition of the Carbohydrates. As stated previously, celery develops a group of leaves with fleshy petioles the first year. Thus, the growth of the plant during the first year may be divided into two stages: (1) The seedling stage, and (2) the petiole thickening stage. Therefore, utilization of the carbohydrates is dominant over accumulation during the seedling stage. As the plants attain their size, utilization becomes less dominant and with the thickening of the petioles, accumulation becomes more evident. Assuming a period of 90 to 120 days for the development of the petioles, the disposition of the carbohydrates is illustrated as follows:

A	seedling stage	B	development of petioles	C
	utilization dominant		accumulation dominant	

PRINCIPAL CULTURAL PRACTICES

Growing the Plants for Transplanting. Celery is always transplanted. The seedling plants are grown in greenhouses, hotbeds, cold frames, or in outdoor beds. In California and in the Southeast outdoor beds are usually used, and in the Midwest and Northeast greenhouses, hotbeds, and cold frames are usually necessary. The "seed" are sown shallowly, either broadcasted or in rows about 8 to 10 weeks from the time the young plants are set in the field. Prior to field setting the seedlings are transplanted, 1½ x 1½ or 2 x 2 inches apart, in beds or flats or allowed to remain in the seedling beds.

Transplanting and Cultivation. Celery is transplanted by hand or by machine. In non-irrigated districts level land is used, and in irrigated districts furrowed land is necessary. The plants are usually set 6 to 8 inches apart either in single or double rows. The distance between rows depends on the method of blanching. In general, the rows are 4, 5, or 6 feet apart for celery blanched with soil, and they are 2, 3, or 4 feet apart for celery blanched by boards or other material.

Blanching, Harvesting, and Marketing. Blanching consists of placing boards or paper on the side of the plants or of covering the lower part of the plants with soil. Blanching partially or wholly destroys the chlorophyll of the petioles and promotes flavor, crispness, and tenderness. Boards or

Fig. 121. A field of mature celery in south Florida. (Courtesy, J. C. Hoffman, U.S. Department of Agriculture.)

special types of paper are used in hot weather, and soil is used in comparatively cool weather. The rate of blanching depends largely on the temperature. Thus, in warm weather blanching is more rapid than in cool weather.

The plants are harvested as soon as they have attained the proper size and the petioles are well blanched. They are sent to markets in two ways: (1) In the rough and (2) fully trimmed. Plants shipped in the rough are cut, partially trimmed—removing damaged and diseased leaves only—packed in crates in the field and shipped to market. Plants shipped fully trimmed are cut, transported to the packing shed, fully trimmed, washed in cool water, graded, packed and sent to market. The principal shipping container is the crate. Various sizes are used. Note the field of mature celery in the Lake Okeechobee district of south Florida.

Chard

Chard is a beet developed *for its fleshy petioles and leaves.* During the first year the plants develop a fleshy taproot, a short stem, and a large number of well-developed, simple leaves. During the second year they develop the flowering stems which support the fruit and seed. The outer leaves mature first. As they are harvested, new leaves develop. In this way the plant produces leaves throughout a relatively long growing season. A rich moist soil is the principal cultural requirement. The plant grows satis-

factorily during moderately warm and cool weather. The petioles are prepared for the table in much the same way as asparagus.

Questions

1. On mineral soils, celery responds to continuous cultivation throughout the growing period. Explain.
2. Celery is grown in late fall, winter, and early spring in Florida; in summer and fall in New York and Michigan; and the entire year in Los Angeles county of California. Explain.
3. Celery thrives best and the petioles attain their highest quality in cool weather. Explain.
4. Celery grown on upland soil in the humid east usually requires irrigation. Explain.
5. Celery thrives well on well-drained, slightly acid mucks with a controlled water table. Explain.
6. The climate of Great Britain is adapted to the raising of high quality celery. Explain.
7. Celery cannot readily compete with weeds. Explain.
8. What is the purpose of blanching celery?
9. How is blanching accomplished: (a) In warm weather? (b) in cool weather?
10. If commercial celery is grown in your state, describe briefly the type of soil used, the system of soil management, the variety, method of plant production, disease control program, and growing and shipping season.
11. In the South celery is rarely grown in home gardens. Can you think of any reasons for this?

THE ANNUALS

Lettuce

PLANT CHARACTERISTICS

Root System. The root system of mature plants is moderately extensive. In upland soil the taproot extends to the 4- or 5-foot level. Branches of the first order extend laterally to a distance of 6 to 8 inches and then turn downward. Branches of the second order are most numerous. They usually fill the upper layer of soil. A direct relation exists between the density of the root system and compactness of the soil. In compact soils the root system is more dense and more shallow than in loose soil.

Stem and Leaves. During the vegetative stage the stem is short, usually from 4 to 6 inches long. Around it the leaves arise in a rosette. They vary in size (large and small), shape (spatular and circular), color (light green

to dark green), and crispness. During the reproductive stage the stems elongate and branch, and each of the various branches forms a terminal inflorescence.

Flowers, Fruit, and Seed. The inflorescence is a panicle. Individual flowers are perfect with five stamens and a one-celled ovary. They are usually self-pollinated. The fruit called "seed" are very small, each contains a single embryo, and are planted shallowly. Investigations have shown that abundant oxygen is necessary for rapid germination. With other conditions favorable, good germination can be obtained from 40° to 70° F.

ECONOMIC IMPORTANCE AND DISTRIBUTION

From 1917 to the present, consumption of lettuce has increased enormously. In 1917 the average per capita consumption was one head; in 1925 it was five heads. In 1929 only 17,000 acres were grown; in 1930 approximately 130,000 acres were grown. This great increase in consumption has been due largely to the education of the public in the health-giving properties of lettuce. Principal producing districts are: the Imperial Valley and Salinas-Watsonville in California, the Oswego in New York, the Wilmington in North Carolina, and the Lake Okeechobee in Florida.

Types. In general, there are two types: (1) The heading and (2) the non-heading. The heading type may be divided into the crisp and the butter. The non-heading type may be divided into the crisp and the cos. Within recent years varieties adapted to specific regions have been developed.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal environmental factor in the growth of lettuce is temperature. For the development of firm solid heads, uniformly cool night temperatures, 45° to 50° F., combined with uniformly cool, sunny day temperatures, 55° to 80° F., is necessary. In humid sections growers very often have difficulty in securing firm, solid heads. High night temperatures, particularly during the heading stage, seem to be the main environmental factor responsible for lack of firmness.

Soils. Lettuce is grown on a wide range of soil types. In California the commercial crop is grown on silty clay loams; in New York and Florida on muck; and in North Carolina on sandy loams. The optimum pH range is from 6.0 to 6.8.

Disposition of the Carbohydrates. The phases of growth to the heading

stage may be divided into two more or less distinct but overlapping periods: (1) Leaf growth and (2) leaf maturation. During the first period the plants are developing their leaves, and utilization of the carbohydrates is dominant over accumulation. As extensive leaf growth subsides and heading begins, utilization processes become less dominant and accumulation processes become more evident. Finally, as the heads become mature accumulation processes become quite marked. Line AB represents a growing period varying from 85 to 100 days, depending on the variety and the season.

	leaf growth →	leaf and head maturation	
A	utilization dominant →	accumulation dominant	B

PRINCIPAL CULTURAL PRACTICES

Growing the Plants. In non-irrigated districts lettuce is grown on level land. The crop may be started directly in the field or in plant growing structures and transplanted. For starting the crop directly in the field, the seed are drilled in rows 12 to 15 inches apart, and the seedlings are thinned to stand from 8 to 12 inches apart in the row. For transplanting the seed are planted in plant growing structures, usually from 8 to 10 weeks before the seedlings are to be set in the field, and they are planted 1½ x 1½ or 2 x 2 inches apart when about 3 weeks old. In irrigated sections lettuce is grown on raised beds. The width of the beds varies from 18 to 20 inches or more and the height from 4 to 10 inches. Two rows, 12 to 16 inches

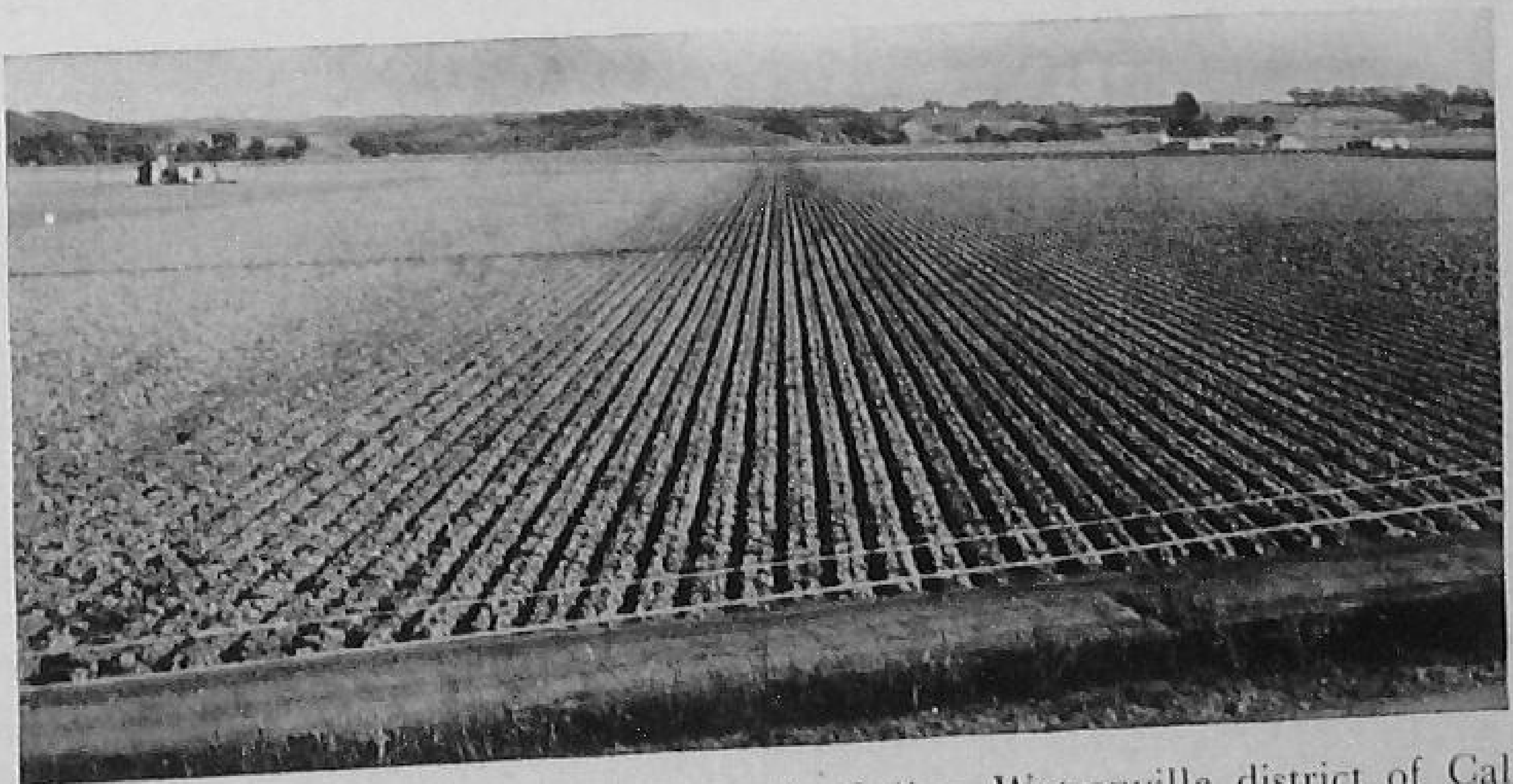


FIG. 122. A field of head lettuce in the Salinas-Watsonville district of California. (Courtesy, Chamber of Commerce and Agriculture of the Pajaro Valley, Watsonville, California.

apart, are planted on the beds. The furrows between the beds carry the irrigation water. Study these features in Figure 122.

FIG. 123. A head of Chinese cabbage. (Courtesy, Associated Seed Growers, New Haven, Connecticut.)

Harvesting. Head lettuce grown for market is allowed to develop solid heads before harvest. When grown in the home garden the heads are frequently harvested before they attain full size. Leaf lettuce is harvested at any time after the plants are large enough for use. The plants are cut usually with a large knife. The heads or plants are trimmed and packed in various types of containers—hampers, crates, or baskets. In packing the stem ends are placed together to avoid injury to the heads in transit.

CHINESE CABBAGE

Chinese cabbage is closely related to, and resembles the members of the cabbage crops. The leaves consist of the edible portion and during the latter stages of growth they form rather loose heads (see Figure 123). They are used for salads or as greens and are fine in texture, succulent, and crisp. In general, the crop thrives best on fertile, moderately to slightly acid sandy loams, loams, and mucks. A continuous supply of available nutrients, particularly nitrogen and water, is essential for steady growth. The heads are harvested when they are well developed. They are cut, trimmed, and packed in baskets, boxes, or crates.

Questions

1. In Florida lettuce is grown during the late fall, winter, and early spring. Explain.
2. In New York lettuce is grown in the summer, and in the Imperial Valley of California it is grown in the winter and early spring. Explain.

3. In general, growth should be rapid during the early stages of plant development and moderately rapid during the later stages. Explain.
4. Comparatively cool, sunny days and cool, crisp nights favor the formation of firm heads. Explain.
5. Lettuce heads stored in the refrigerator remain more sweet and crisp than those stored in a warm room. Explain.
6. Name the two types of lettuce.
7. Within the past 30 years consumption of head lettuce has increased rapidly. Explain.

Spinach

PLANT CHARACTERISTICS

Root System. Spinach has a distinct, well-developed taproot. The laterals are relatively few and short. Most of the absorbing roots arise directly from the taproot.

Stems and Leaves. The stem is short and plate-like and bears a rosette of well-petioled simple, moderately large leaves. The leaves vary in shape (spear-shaped to round) and character of the surface (smooth, slightly undulated or savoyed). The savoyed surface is due to extensive growth of the parenchyma tissue between the veins. The leaves are exceedingly dark green. They are an excellent source of carotene (provitamin A), ascorbic acid, and minerals, as well as being a good source of thiamin and riboflavin.

Flowers, Fruit, and Seed. Spinach is dioecious and monoecious according to the variety. In dioecious varieties the males are of two types: (1) Extreme and (2) vegetative. The extreme males have few, if any, well-developed leaves toward the tip of the seed stalk and the vegetative males have well-developed leaves toward the tip. Since spinach is grown for its leaves in home and commercial gardens, vegetative males are more desirable as breeding parents than extreme males. Female plants are always vegetative. Thus, highly vegetative strains of the dioecious varieties have been developed by roguing out the extreme males in seed-producing fields. In monoecious varieties the plants are highly vegetative.

The flowers are without petals, small, and relatively inconspicuous. Pollen grains are small, produced in abundant quantities, and are carried from one plant to another by the wind. The fruit called "seed" have the ability to germinate at rather low temperatures and require a continuous supply of water. Poor germination frequently occurs in dry soil in the summer.

ECONOMIC IMPORTANCE AND DISTRIBUTION

Spinach is the most important vegetable crop grown as greens. Principal commercial areas are in the vicinity of Baltimore, Maryland; Norfolk, Virginia; Crystal Springs, Texas; and in central New Jersey and southern California. The Virginia and New Jersey districts supply markets during the fall and spring; the Texas district supplies markets in the winter and early spring; and the California district supplies the Pacific Coast markets during the winter. The principal districts which are given over to the raising of spinach for canning are located in California and in south Texas.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal environmental factors affecting the growth of spinach are temperature and length of the day. Spinach is primarily a cool-season, long-day plant. From the standpoint of temperature, it thrives best in regions characterized by cool nights (40° to 50° F.) and clear sunny days (60° to 80° F.). From the standpoint of photoperiod, it produces leaves and stems during the short days, and flowers and fruit during the long days. For this reason spinach is grown in home and commercial gardens in the short days of late fall, winter, and early spring and for seed production during the long days of summer.

Soils. Spinach is grown on a wide variety of soil types. The greatest yields are secured from silt and clay loams and mucks. However, sandy loams are used to grow winter crops. In any case soils for spinach should be slightly acid, well drained, and fertile.

Disposition of the Carbohydrates. As stated previously, in home and commercial gardens spinach is grown primarily for its leaves. Thus, during the seedling stage most of the carbohydrates that are made are used for cell division and enlargement. As the plants attain their size, leaf growth becomes less rapid, carbohydrate utilization in turn becomes less rapid, and accumulation becomes more evident. Line AC, representing a growing period of 45 to 80 days, roughly indicates the period of leaf growth and leaf maturation.

A	period of leaf growth	B	period of leaf maturation	C
	utilization dominant	→	accumulation dominant	

FIG. 124. A field of spinach in eastern United States. (Courtesy, V. R. Boswell, U.S. Department of Agriculture.)

PRINCIPAL CULTURAL PRACTICES

In general, spinach is raised on level land without beds in northern regions and on broad, low beds varying from 8 to 12 feet wide in southern and irrigated regions. The "seed" are usually drilled in rows from 12 to 24 inches apart depending on the variety and method of culture. The wider spacing of the row is followed wherever horse cultivation is practiced. Spacing of the plants is regulated as far as possible by adjusting the rate of seeding. Although complete fertilizer mixtures are used in most districts, nitrogen is considered the most important nutrient element, and a steady available supply is necessary. The cool weather during the winter in southern districts and the growing of the crop on well-drained, sandy loams, necessitates frequent top dressings of readily available nitrogen. Note the close spacings within and between the rows in Figure 124.

Preparation for market consists of cutting the taproot just below the surface of the land and trimming off the dead leaves. For long distance shipment, spinach is usually packed in bushel hampers or crates. When shipped in warm weather, crushed ice is placed in the upper part of the containers.

Questions

1. Spinach in home and commercial gardens is grown during the fall, winter, and early spring. Give two reasons.

Assign. 27

2. Spinach grows poorly on soil greater than pH 7.0 and less than pH 6.0. Explain.
3. Investigations have shown that spinach requires abundant moisture and nutrients, particularly nitrate-nitrogen. Explain.
4. Spinach maturing in the late fall is sweeter than that maturing in late spring. Explain.
5. Since 1910 spinach has become very popular in the United States. Can you think of any reasons for this?

20

Vegetable Crops Grown for Their Fleshy Vegetative Structures

Assignment 28

THE ONION CROPS

Common Characteristics. The onion crops consist of onion, shallot, leek, garlic, and chive. These crops have, at least, four characteristics in common: they possess a characteristic odor and flavor, store carbohydrates in the basal portion of the leaves, develop a non-extensive root system, and produce perfect, insect-pollinated flowers. The characteristic odor and flavor vary with the crop and with the variety within the crop. For example, garlic is more pungent than onions, and the American varieties of onions are more pungent than the European varieties. The basal portion of the leaf is thick and fleshy and constitutes the edible portion. These basal leaves with the short plate-like stem are called bulbs and contain comparatively large quantities of inulin (a type of starch), moderate amounts of sugars and moderate amounts of ascorbic acid or vitamin C. The non-extensiveness of the root system, with the major portion of the absorbing system of mature plants within a radius of 6 inches from the stem, requires the absolute control of weeds and the selection of soils with high water-holding capacity. The leaves are simple and present a rather small photosynthetic surface. The inflorescence is an umbel; individual flowers possess six stamens and a simple pistil; and they are chiefly pollinated by various species of bees.

ONION

Distinguishing Characteristics. The onion develops *distinct bulbs*. According to the variety, these bulbs vary in size (small, medium, and large), color (white, yellow, or red), shape (flattened, round, or globular), texture (fine or coarse), and pungency. The plant is normally a biennial. The fleshy bulbs develop during the first season, and seed stalks develop during the following season. The leaves develop from a short flattened stem at the base of the bulb. They consist of two parts: (1) The sheath and (2) the blade. The sheaths are fleshy and surround the younger leaves within. The blades are green, pointed, and hollow.

Economic Importance and Distribution. Of the onion group, the onion is the most widely grown and the most commonly known. In the United States extensive commercial districts are located in south Texas and Louisiana, in the Pacific Coast region and Rocky Mountain area and in the Northeast and Midwest region.

Types. Onions are classified according to the degree of mildness of the bulb. Three distinct types are recognized: (1) Mild, (2) semi-mild, and (3) pungent or strong. In general, the mild type develops larger, finer textured bulbs than the pungent or strong type. The commercial varieties of onions are rather specific in their optimum growing requirements. For example, the long-storage pungent varieties grown in the Midwest and Northeast do poorly in the Southwest and Pacific Coast, and the non-storage mild varieties grown in the Southwest are ill suited to the Midwest and Northeast.

GROWTH AND DEVELOPMENT

Climatic Requirements. Onions require a cool temperature range during the seedling stage and a moderately high temperature range during the bulbing stage. The moderately high temperature, particularly if combined with a dry atmosphere, facilitates harvesting and curing of the bulbs. Thus, the crop is grown in winter and early spring in southern regions and during the spring and summer in northern regions. The late summer of the Northeast and Midwest region is sufficiently warm to permit normal curing of the varieties adapted to that region.

The principal factors influencing the formation of the bulb are: (1) The supply of available nitrogen and (2) the length of the day. If excessive quantities of available nitrogen are present, and with other factors favorable, vegetative growth will be excessive and undesirable bulbs will be

formed. These undesirable bulbs are known as "thick-necked onions" or scallions. They lack quality, have low market value, and possess poor keeping ability. If the length of the day is unfavorable for bulb formation of any given variety, no bulbs will be formed. Varieties differ in their length of day requirements. Some require a long period (15 to 17 hours), while others require a relatively short period (12 to 14 hours). Thus, varieties adapted to the northern half of the country are unadapted to the southern half and vice versa.

Soils. Onions thrive best on highly fertile, slightly acid, well-drained sandy loams, silt loams, and mucks. For example, in the winter garden area of Texas, the crop is raised on sandy loams, and in New York, Ohio, and Michigan highly decomposed mucks are employed. These soils are loose, thus permitting normal development of the bulb, and have a high water-holding capacity.

Disposition of the Carbohydrates. As previously stated, the bulb is produced during the first season and seed stalks are produced during the second. During the first part of the first season the plants are developing their leaves and roots, and during the latter part they are developing their bulbs. Consequently, environmental conditions should permit extensive foliage and root growth before bulbing begins. Since foliage and root growth precede bulb formation, carbohydrate utilization will be dominant during the first part of the growing season, and carbohydrate accumulation will be dominant during the latter part.

A	growth of roots and leaves ⟶	B	development of bulbs	C
	utilization dominant ⟶		accumulation dominant	

Line AC represents a growing period of 100 to 120 days of the first year. Line AB represents the period of root and foliage growth and line BC represents the period of bulb formation.

PRINCIPAL CULTURAL PRACTICES

Planting. In the United States three distinct methods are used to start onions. These are: (1) Planting seed directly in the field, (2) planting seed in prepared seed beds and transplanting the seedlings to the field, and (3) planting dry sets where the crop is to mature. The first method is practiced largely in the Midwest and Northeast. In general, the seed are sown in rows 8 to 18 inches apart at the rate of 3 to 4 pounds of seed per acre. Hand- and power-driven drills are used to plant the seed. The second method is used principally in Louisiana and south Texas. Seedling plants

are set 4 to 6 inches apart in rows 12 to 24 inches apart. The third method consists of planting the sets 3 to 6 inches apart in shallow furrows.

Growing the Crop. As previously stated, onions are grown on mineral soils and on muck. Satisfactory mineral soils are well drained, slightly acid, and contain moderate quantities of decomposed organic matter. Experiments in Texas, Louisiana, and Virginia indicate that commercial fertilizers high in phosphorus produce the highest yields. A 1–3–0 ratio is recommended for the winter garden district of Texas and a 1–2–1 ratio for the soils of eastern Virginia. Satisfactory muck soils are deep, highly decomposed, and slightly acid. Experiments in New York, Michigan, and Ohio have shown that mixtures high in potash are necessary. Recommended mixtures are: 2–8–16, 3–9–18, 3–12–15, 3–12–18, and 0–12–18. To develop deep color and thick scales of the bulbs, applications of powdered copper sulfate are necessary in many districts.

Because of its sparse root system and small top, the onion cannot compete readily with weeds. In fact, of the entire vegetable crop group, onion yields are easily reduced by weeds. Thus, weeds have no place in the onion plantation.

Harvesting and Marketing. The mature bulbs are pulled by hand and placed in windrows to cure. Later they are topped, graded according to size, and placed in crates if they are to be stored (see Figure 125); or placed in 50-pound open mesh bags if they are to be shipped. Onions are shipped to the markets of the country throughout the entire year. Cali-

Fig. 125. A field of onions in Nebraska, stacked in crates for curing. (Courtesy, H. A. Jones, U.S. Department of Agriculture.)

fornia ships during every month of the year; Texas ships from May to August; and the northern states ship from September to April and May.

Shallot, Leek, Garlic, and Chive

The shallot develops *several small bulblets or cloves held together at the base;* the leek develops *thick, mild, fleshy leaf sheaths;* the garlic develops *a group of small bulbs or cloves enclosed in a membrane-like skin;* and chive develops *small distinct bulbs.* Commercial districts of shallots exist in southern Louisiana, and commercial districts of garlic are located in central California. The climate and cultural requirements are similar to those of the onion.

Questions

1. In general, the onion group of crops require continuous cultivation, they cannot compete readily with weeds, and can be planted at close distances. Explain.
2. In ancient times masters of sailing vessels frequently took on a supply of onions before making long voyages. Explain.
3. Distinguish the three main types of onions.
4. In the southern regions onions are grown in the winter and early spring; in northern regions they are grown in the summer. Explain.
5. Onions are particularly adapted to loose, friable loams and to slightly acid mucks. Explain.
6. In general, the larger the plants grow before they begin to form bulbs, the larger will be the yield. Explain.
7. In what regions of the United States are most of the pungent varieties of onions grown; in what region are most of the mild types grown? Give reasons for your answer.
8. Name and distinguish the members of the onion group.

THE TUBER CROPS

The Potato*

PLANT CHARACTERISTICS

Root System. The root system of asexually propagated crops is fibrous and adventitious. In other words, the roots arise from the nodes of the stem situated in the soil. In adult plants the root system is moderately extensive. Although a few roots extend from 3 to 4 feet, both vertically

*In southern United States the term "potato" usually refers to the sweetpotato and the potato is called the Irish potato.

and laterally, most of the roots are from 6 inches to 2 feet long. These roots are situated in the topsoil with the greater density in the upper 3 to 4 inches. Hence, if cultivation is necessary during the later stages of growth, it should be shallow to avoid cutting the absorbing roots just beneath the surface.

Stems and Leaves. The stems are of two types: (1) Aerial and (2) underground. The aerial stems are angular, green or greenish purple depending on the variety and bear in a spiral arrangement pinnately compound leaves. Under humid conditions the leaves are broad and flat, and under arid conditions they are narrow and cupped.

The underground stems consist of stolens and tubers. The stolens are about the size of a lead pencil and extend laterally for a distance of 1 to 4 inches. The tubers arise at the end of the stolens and are short, thick, and fleshy. They develop scale-like leaves called "eyebrows" which subtend buds called "eyes." These buds are undeveloped branches. Each eye contains both terminal and lateral branches, and each potato has both terminal and lateral eyes. The terminal eyes develop sprouts before the lateral eyes, and the terminal sprouts in each eye develop before the lateral sprouts. However, cutting of the tubers, an important practice, destroys the dominance of the terminal eyes, and removing the first sprouts destroys the terminal dominance within each eye.

The anatomy of immature and mature tubers differs considerably. The anatomy of immature tubers consists of an epidermis, a wide band of cortex, pericycle, vascular bundles, and pith. As the tuber develops the epidermis is replaced by a periderm—the layer of cork-like cells. The cortex becomes a narrow band just beneath the periderm and the vascular bundles extend to the eyes. The pith becomes greatly enlarged and constitutes the major portion of the tuber. The function of the periderm is to keep the all-important water within the tuber and to resist the attacks of rot-producing organisms. The lenticels permit exchange of carbon dioxide and oxygen, and the cortex and pith are abundantly filled with grains of starch. In fact, most of the dry matter of the tuber consists of starch.

Flowers, Fruit, and Seed. The flowers are borne in clusters terminating the stem. Individual flowers are perfect and white, yellow, purple, or striped according to the variety. Flowering is usually more profuse in regions characterized by low summer temperatures than in regions characterized by high summer temperatures. The fruit or seed ball is round, small —½ to 1 inch in diameter—and contains from 100 to 300 seeds. Seed are used to develop new types and varieties.

ECONOMIC IMPORTANCE AND DISTRIBUTION

The potato is the most important, most valuable, and most widely known horticultural crop. The annual world production is between 6 and 7 billion bushels and is exceeded only by that of wheat. The leading countries are Russia (1½ billion), Germany (1½ billion), Poland (1 billion), and France and the United States (½ billion each). In the United States two rather distinct commercial industries exist: (1) The main-crop and (2) the early-crop. Important main-crop producing districts are: Aroostook County, Maine; western New York; eastern Pennsylvania; northern Ohio; central Michigan; Red River Valley of Minnesota; high altitude areas of Idaho; and eastern Nebraska. The potatoes are harvested when they are fully mature and are placed in storage to supply the markets in the winter and early spring. Important early-crop producing districts are: Mobile Bay, Alabama; Hastings and Homestead, Florida; south Texas; south Louisiana; Charleston-Beaufort, South Carolina; Norfolk, Virginia; Long Island, New York; and Sacramento Delta, California. The potatoes are harvested when immature and are prepared and shipped immediately to the markets. Thus, the many regions of the country supply the consuming public with this important vegetable throughout the year.

Varieties grown in the United States are placed in two groups: (1) Early-maturing and (2) late-maturing. Early-maturing varieties develop tubers in a relatively short time, and late-maturing varieties require a relatively long time. In general, the early market varieties are adapted to the southern regions of the country, and the main-crop varieties are adapted to the northern regions. Because of extensive breeding programs, particularly in the United States Department of Agriculture in coöperation with many state experiment stations, new varieties are constantly being developed. For the most part, these new varieties combine disease resistance of the tops with high yields of high quality tubers.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal climatic factor influencing growth and yield is temperature. The potato plant thrives best in uniformly cool weather. In general, the optimum temperature range is considered to be between 45° and 65° F. with a mean of about 60° F. In other words, the highest yields are secured within this temperature range. As explained in Chapter 4, if the temperature is above this range, particularly during the period of tuber formation, yields are low. The high yields

secured in Maine, in the British Isles, and in northern Germany are due largely to the comparatively low temperatures in these regions during the period of tuber formation and development.

Soils. In general, the potato is grown on fertile sandy loams and mucks. On mineral soils the addition of decayed organic matter is usually beneficial. Organic matter improves texture and aeration, and thus makes the soil more favorable for the development of the tubers. The Wooster and the Washburn series of loams are used in Aroostook County, Maine, the most important potato growing county in the United States. Well-drained sandy loams are used in New Jersey, New York, Virginia, and in many of the southern states. Both muck and mineral soils are used in Florida, Michigan, and Wisconsin.

Disposition of the Carbohydrates. Since the tuber is the place where carbohydrates accumulate, the yield of the tubers is an expression of carbohydrate accumulation. Before tuber formation can take place stems and leaves (food-manufacturing structures) and roots (water- and nutrient-absorbing structures) must be formed. Hence, when the plant is developing its root and top systems, it is making numerous new cells and large quantities of carbohydrates are necessary for their formation. Consequently, during the early stages of growth the utilization of carbohydrates is dominant over accumulation. On the other hand, when the plant begins to develop its tubers, root and top growth practically ceases and the carbohydrates become available for tuber formation. Consequently, during the period of tuber formation and development, carbohydrate accumulation is dominant over utilization. Line AB, representing a growing period of from 120 to 200 days, shows the periods within which utilization and accumulation are taking place. The student should remember that there is a gradual transition from the development of roots and tops to the development of the tubers.

	growth of tops and roots	formation of tubers	development of tubers	
A	utilization dominant	⟶	accumulation dominant	B

PRINCIPAL CULTURAL PRACTICES

Production of Tubers for "Seed." As previously stated, in home and commercial gardens potatoes are propagated by means of the tubers. Since the tubers are storage stems, they contain terminal and lateral buds and large quantities of starch. Under conditions favorable for development of the buds, the starch changes to sugars which are used to make new cells and to supply energy for the growth of the young plants.

The raising of tubers for starting new crops is a highly specialized industry. At present many varieties are susceptible to many virus diseases. These virus diseases are carried from one crop to the next in the tubers, and from infected plants to healthy plants by certain insects. If virus diseases are present in any plant they impair the development of chlorophyll, reduce the photosynthetic process, and markedly decrease the yield. Consequently, tubers grown for starting other crops should be practically free from these diseases. In general, plants for "seed" are grown in regions characterized by cool weather and under certain rules and regulations. The cool weather favors the development of virus disease symptoms of infected plants. The rules require the inspection of plants to remove specimens infected with the virus diseases, the control of insect vectors, and the inspection of tubers in storage. Crops which have passed the requirements of inspection are given a certificate and can be sold as certified "seed." Principal certified "seed" producing districts are located in Maine, and Maritime Provinces of Canada, New York, Wisconsin, Michigan, North Dakota, Nebraska, and the mountain sections of Maryland, North Carolina, Georgia, and Tennessee.

Establishing the Plantation. The tubers are cut just before planting into three, four, five, or six pieces depending on the size of the individual tuber. Many scientists have conducted tests to determine the most economical size of the seed piece. In general, the tests have shown that each piece should weigh from 1 to 1½ ounces and have at least one good eye.

The pieces are planted by hand or by machine from 10 to 18 inches apart in rows 30, 33, 36, or 48 inches apart depending on the variety, the producing district and intensiveness practiced. In the winter garden areas of the South the "seed" is usually planted by hand, and in the producing districts of the North the "seed" is usually planted by machine. Under favorable conditions of temperature, moisture, and air, shoots develop from the eyes of the tuber. The terminal portion pushes through the soil and develops into the top system, and from the underground portion of the stem develops the moderately extensive root system. Until the young plant develops mature leaves, it is dependent on the food supply in the tuber for its growth and development.

Nutrition. From the time the plant begins to make food to the time of tuber formation, the potato requires large quantities of nutrients. To supply these nutrients complete fertilizer mixtures are used. The exact analysis and the amount applied vary with the producing district. In general, 6-8-6 and 5-8-7 mixtures are popular in the winter garden areas in the

South, and 4–16–4 and 5–10–5 mixtures are used in the North. Applications vary from 600 to 3000 pounds per acre depending on the type of soil and the purpose for which the crop is grown. The nutrients are applied in the furrow about 1 week or 10 days before the tubers are planted or with the potato planter with a fertilizer attachment. For many years scientists have tested various methods of applying the commercial fertilizer. Many of these tests show that applying the nutrients on the side of the seed piece produces greater yields than applying the fertilizer under the seed piece.

Cultivation. By the time the plants begin to flower or produce flower buds they have developed the shallowly situated, moderately extensive root system, and they are beginning to develop the tubers. Thus, deep cultivation, particularly after the plants have blossomed, is likely to cut the feeding roots just below the surface and to reduce the yields. In general, shallow cultivation is practiced and only when weed control or breaking of the soil crust is necessary. Figure 126 is a harvest scene of potatoes in the Mobile Bay district of south Alabama.

Harvesting, Storing, and Marketing. As previously stated, from the standpoint of the market, the growing of potatoes may be divided into two industries: (1) For market immediately after the harvest and (2) for storage or deferred shipment. In general, potatoes grown in the commercial areas of southern regions are marketed immediately after the harvest. The

FIG. 126. Harvesting potatoes in the Mobile Bay district of south Alabama. (Courtesy, The Mobile Press Register, Mobile, Alabama.)

tubers are dug when they are immature, washed and packed in burlap bags, and immediately shipped to market. On the other hand, tubers grown in northern regions are marketed after a period of storage. The tubers are dug when mature, placed in storage (temperatures 40° to 42° F. with moderate humidity) and later shipped to the market. For the retail trade in large cities potatoes are attractively packed in 15-, 20-, or 25-pound lots in paper boxes and in cotton or burlap sacks.

Questions

1. In general, the potato requires shallow cultivation particularly during the period of tuber formation. Explain.
2. Potatoes harvested in the immature state skin easily. Explain.
3. Investigations have shown that potatoes with a well-developed periderm shrink less and rot less in storage than those with a poorly developed periderm. Explain.
4. The climate of northern Maine, the Delta district of California, Great Britain, and Ireland is particularly favorable for the production of high yields of potatoes. Explain.
5. Potatoes are grown in late winter and early spring in southern regions; in the summer in northern regions. Explain.
6. If soil and air temperatures are above the optimum range, particularly during the later stages of growth, yields will be extremely low. Explain.
7. In the southern regions, with due consideration to the date of the last killing frost, the earlier the planting the greater is likely to be the yield. Explain.
8. In Colorado potatoes are grown in the mountains and yields are satisfactory. Explain.
9. What is certified "seed" of the potato?
10. Carefully handled tubers have longer storage life than carelessly handled tubers. Explain.

The Jerusalem Artichoke

The Jerusalem artichoke is a tuber-forming sunflower. The root system is undoubtedly extensive. The stems consist of two types: (1) Underground (tubers) and (2) aerial. The tuber stores a type of starch called inulin and develops in much the same way as that of the potato. In the United States experiments have shown that the crop is better adapted to the northern two thirds of the country than it is to the southern one third.

THE ROOT CROPS

The vegetable crops called the root crops include carrot, parsnip, salsify, beet, radish, turnip, rutabaga, and horseradish. These crops develop enlarged vegetative structures called roots. They contain fairly large quantities of starch, and the size, shape, color of skin, and flesh vary greatly with the crop.

Common Characteristics. The root crops are herbaceous biennials except the radish which is either annual or biennial. They develop an extensive absorbing system, long petioled leaves, and they thrive best in cool weather and have similar cultural requirements.

Growth and Development. The growth and development of root crops may be divided into two distinct periods: (1) The production of the enlarged vegetative structure and (2) the production of flowers, fruit, and seed. In home and commercial gardens these crops are grown for the enlarged structure only. Hence, the disposition of the carbohydrates during the first period of growth only will be considered. Before the enlarged portion develops the plant produces most of its leaves and absorbing roots. The roots absorb the necessary water and nutrients for the manufacture of food in the leaves. Thus, the development of leaves and of absorbing roots is necessary before the development of the enlarged portion can take place. To develop leaves and absorbing roots carbohydrates are necessary. Thus, during the seedling stage utilization of carbohydrates is dominant over accumulation. Later after the leaves develop, utilization is less dominant and carbohydrates begin to accumulate. The disposition of the carbohydrates is shown as follows: line AB represents a growing period varying from 35 to 90 days depending on the kind of crop.

growth of roots and leaves ⟶ development of fleshy structure

A utilization dominant ⟶ accumulation dominant B

Carrot

The carrot is the most important vegetable root crop. A transverse section of the fleshy root shows two distinct regions: (1) The outer core and (2) an inner core. The outer core consists of a thin periderm and a relatively wide band of storage tissue. The function of the periderm is to reduce transpiration to a minimum and to resist the attacks of invading organisms when the roots are in storage, and the function of the storage tissue is to store relatively large quantities of starch and carotene (the precursor of vitamin A) and moderate quantities of sugar, thiamin, and ribo-

flavin. The inner core consists of xylem and pith. The function of the xylem is to conduct water and nutrients and the pith is for storage. High quality carrots contain a relatively large outer core. Scientists have shown that the outer core contains more carotene than the inner core.

Stems, Leaves, Flowers, and Fruit. The stem is short and plate-like during the first growing season and long and erect during the second. The leaves are decompound and the inflorescence is a conspicuous compound umbel. Individual flowers are small, hermaphroditic, and white and are largely insect-pollinated. The fruits are called "seed" and are small, dry, and indehiscent. Each individual fruit contains one seed. The embryo germinates slowly, requires a fine friable seed bed and uniform supplies of moisture.

Economic Importance and Distribution. From the standpoint of human nutrition the carrot is most important. Because the enlarged root contains large quantities of carotene, it is an excellent source of vitamin A. Within recent years the demand for carrots has been quite marked. In 1926 about 19,000 acres were grown and in 1945 about 45,000 acres were grown. Principal producing states are: California, Texas, New York, New Jersey, Arizona, Louisiana, and Florida. California and the southern states supply the markets with carrots during the winter and spring. New York and other northern states supply the market with carrots during the fall and winter.

Growth and Development. Although the nutrient and light supply influence the growth of carrots, scientists have shown that the effects of temperature and moisture are quite pronounced. The optimum temperature range for the growth of the tops seems to be from 65° to 75° F. and that for the growth of the roots seems to be from 60° to 70° F. Since size and carotene content of the fleshy root are dependent on the size and health of the foliage, comparatively high temperatures (65° to 85° F.) during the seedling stage permit the development of a large top and somewhat lower temperatures (60° to 70° F.) after the tops are fully grown permit the development of large, highly colored roots.

Even in the presence of favorable temperatures, the development of well-shaped, highly colored roots requires the use of moist soil. Investigations have shown that excessive soil moisture produces undesirably short, thick roots which are low in carotene and poor in color. Thus, well-drained soils, particularly in regions of heavy rainfall, are necessary for the production of carrots of high quality.

Culture. As indicated in the preceding paragraph, satisfactory soils for

carrot culture should be well drained. In addition, they should be moderately to slightly acid, non-self-crusting and free from large quantities of undecomposed organic matter. In general, sandy loams in good tilth are preferred and self-crusting silts and clays are avoided. Well-drained, moderately to slightly acid, sandy loams are advantageous from three standpoints: (1) They permit the emergence of the delicate plumule during germination, (2) they promote rapid growth of the plants, and (3) they favor the development of smooth, highly colored roots.

Although complete fertilizers are used for the production of carrots, nitrogen seems to be more frequently limiting in growth than phosphorus or potassium. This is particularly true during the early stages of growth. As previously stated, a comparatively large top is necessary for the development of a large root. Hence, the supply of available nitrogen should be sufficient to promote a rapid development of the top and to maintain health and vigor of the top during the period of root formation.

In general, the seed are planted about ⅛ inch deep, just enough to cover them with soil. Time of planting varies with the producing district. In Louisiana the early or midwinter crop is planted in the early fall and the late or spring crop is planted in the winter. In the Beaufort-Charleston truck crop district seed is sown usually between October 15 and November 30, and in New York and Michigan plantings are made in April and May. Carrots are prepared for market either with or without the top. Those harvested with the top are tied in bunches and are called bunch carrots. Bunched carrots usually are shipped in crates and unbunched carrots are shipped in bulk.

Varieties are classified according to shape and length of the root. Shape refers to the tip of the root, whether blunt or pointed, and length is considered with reference to the diameter. Principal classes are: moderately long and blunt; long and blunt; long and pointed; and very long and pointed. Within recent years scientists have developed highly colored strains of certain varieties which are adapted to specific producing districts in the country.

Parsnip and Salsify

Parsnip and salsify develop enlarged roots which have white flesh without distinct zones. For full growth and development both crops require a relatively long growing season and the cultural requirements are practically the same as those for carrots. With parsnips the freezing of the roots is unnecessary to improve the quality. At College Park, Maryland, parsnips

stored for 2 weeks at 34° F. became just as sweet as roots left in the soil for 2 months in the late fall. At 34° F. the change of starch to sugars was quite rapid. In the United States the crop is grown in many home gardens and in limited quantities in market gardens.

Beet

The enlarged root of the garden beet is quite distinct from that of the other root crops. A cross section shows alternate circular bands of storage and conducting tissues. The broad bands are storage tissues and the narrow bands are conducting tissues. Frequently, the wide bands are darker than the narrow bands. The contrast in color between these alternate bands is known as "zoning." Zoning varies greatly between varieties and within varieties and with the environment. Distinct zoning is undesirable. Many strains of the principal varieties have been developed which are fairly uniform in color.

The leaves are simple and are arranged on a short stem called the crown. They vary from dark purple to light green. The fruit called the "seed ball" usually consists of several ovaries, each of which contains a single seed. Since most seed balls contain more than one seed, thinning of beet seedlings is necessary.

Beets are grown in home gardens, in commercial gardens, and for canning. The winter garden areas of the South and California supply the markets with beets during the winter and spring, and producing districts in the North supply the markets in the summer and fall and grow crops for canning.

Radish

The enlarged root of the many varieties and types of radish vary greatly in color, shape, size, season of maturity, and texture of the flesh. Varieties are generally classified according to the length of time the roots attain maturity. Three groups exist: (1) Spring, (2) summer, and (3) winter. In general, spring varieties grow quickly and mature their roots in a relatively short time (25 to 30 days); summer varieties grow less quickly and mature their roots in a relatively long time (45 to 50 days); and winter varieties grow slowly and produce large roots which have a long storage life under favorable conditions. The leaves are simple and are arranged in the form of a rosette on a short stem. Later the stem elongates and produces flowers, fruit, and seed.

Radishes are grown in most home gardens, particularly in early spring.

The crop has minor importance commercially. Most market gardeners and greenhouse growers produce small quantities to supply local markets, and truck crop growers in a few localities in the South produce radishes for long distance shipment.

Turnip and Rutabaga

Turnips and rutabagas are closely related and have characteristics in common and characteristics in distinction. In general, the characteristics in common are: the necessity for cool weather, moist, moderately fertile, slightly acid soil, and similar cultural requirements; and characteristics in distinction are: for the turnip, green, hairy leaves, an indistinct crown, and a relatively small root; and for the rutabaga, gray-green, non-hairy leaves, a distinct crown, and relatively large roots. With turnips two groups exist: (1) White and (2) yellow. Of these the white-fleshed group is the more widely grown. Within this group certain varieties are grown primarily for their tops for use as greens and other varieties are grown primarily for their fleshy roots. Turnip greens are excellent sources of carotene, thiamin, riboflavin, ascorbic acid, and minerals.

Horseradish

Horseradish is grown for thick fleshy white roots which have a pungent flavor. The fleshy roots are ground, preserved in vinegar, and used as a condiment. The pungent compounds are soluble in water but are volatile, hence ground horseradish root is kept in sealed containers. The plants form a rosette of long petioled, narrow, dark green leaves.

The fleshy roots attain their best development in well-drained deep loess and sandy loams. In shallow or "hard" soils the roots become branched, sprangly, and rough. The crop is propagated asexually. Lateral roots ¼ to ½ inch thick and from 8 to 12 inches long are saved at the time the main roots are prepared for market, stored during the winter, and planted in the spring about 12 inches apart in rows 36 inches apart in deep friable soil. Since the lateral roots are distinctly polar—producing shoots at the stem end and roots at the root end—the stem end is cut obliquely and the root end is cut square. In this way the planter knows which end to plant uppermost. To obtain smooth, large roots many growers cut away the fleshy laterals from the main root. The principal commercial district is located near St. Louis, Missouri. The deep loess in this vicinity is particularly favorable to the development of large, smooth roots. Other commercial areas exist in New York and New Jersey.

Questions

1. Name three common characteristics of the vegetable root crops.
2. Young carrots contain less carotene than old carrots. Explain.
3. The development of a large top during the early stages of growth is necessary for the development of highly colored roots. Explain.
4. In Louisiana two crops are grown each year. The fall crop matures in December and January, and the spring crop matures in May and June. Usually the roots of the fall crop are more highly colored than those of the spring crop. Explain.
5. In general, beets harvested in the summer have poorer color than those harvested in the fall. Explain fully.
6. Usually, the spring varieties of radishes maturing in hot-dry weather tend to become pithy. Explain.
7. Parsnip roots become sweet after exposure to subfreezing temperatures. Explain.
8. Distinguish between turnips and rutabagas.
9. Turnip greens are more widely adapted to growing in southern home gardens than spinach. Give two reasons.
10. In general, mature root crop vegetables possess a well-developed periderm. They keep satisfactorily in storage pits and banks. Explain.

The Sweetpotato

PLANT CHARACTERISTICS

Root System. The root system consists of: (1) An extensive absorbing system and (2) fleshy roots. The fleshy roots are small at first; later the base of most of them becomes thickened. A few become much thickened and form the edible roots. These enlarged roots have a typical root structure. The young root has an epidermis, a relatively thick cortex, a pericycle, endodermis, and radial bundles. As the root enlarges and matures, a periderm with lenticels takes the place of the epidermis. Cambium arises between the phloem and secondary xylem and phloem is produced in scattered strands.

The function of the periderm, as in the case of the potato, is to keep the all-important water within the fleshy root and to resist the attack of rot-producing organisms. Its formation is influenced by temperature and relative humidity. Investigations have shown that high temperatures, 80° to 85° F., combined with high humidity, 80 to 85 per cent, greatly facilitate periderm formation. Since, at the harvest, the periderm is not fully developed and is easily bruised by handling, the primary purpose of curing is to heal the bruised surfaces and to thicken the skin.

The fleshy root is primarily a storage organ. It contains large quantities of starch which gradually change to sugar. According to the variety, color of the skin varies from creamy white to dark red, and color of the flesh varies from white to salmon pink. Thus, some varieties possess the ability to make carotene while others do not.

Stems and Leaves. The sweetpotato produces a relatively large top which consists of a main axis and primary laterals. The stems vary in length depending on the variety and the environment. For example, the so-called "vineless" sorts produce stems from 2 to 4 feet in length, and the so-called "viny" sorts produce stems from 6 to 20 feet in length. For the same variety soils with abundant nutrients, particularly nitrogen, combined with optimum moisture and favorable temperature produce plants with longer stems than soils supplied with moderately abundant nutrients and low water.

The leaves are long petioled, simple, cordate, and slightly or deeply lobed depending on the variety. The veins are prominent on the lower surface and usually show the same degree of pigmentation as the stems.

Flowers, Fruit, and Seed. The flowers are perfect, axillary and resemble those of the morning-glory. They occur singly or in clusters on stout peduncles. Color of the corolla varies from white to light purple. In general, there are five stamens clustered around a single superior pistil. The fruit is a round, hairy or non-hairy pod which contains from one to five seeds. The mature seed are black, angular, and have a hard coat. This coat greatly delays germination of the seedling. Recent tests have shown that soaking the seed in concentrated sulfuric acid followed by washing scarifies the seed coat and insures prompt germination.

ECONOMIC IMPORTANCE AND DISTRIBUTION

The sweetpotato is a major horticultural crop in the southern regions of the United States. Important commercial districts are: the San Joaquin and Coachella of California, the Gilmer of east Texas, the Sunset and Oak Ridge of Louisiana, the Edwards of Mississippi, the Mobile Bay of Alabama, the Orangeburg of South Carolina, and the Norfolk-Eastern Shore of Virginia.

Varieties are placed in two groups: (1) Varieties grown for table stock and (2) varieties grown for starch and/or feed. Varieties grown for the table are in turn divided into two groups: (1) The dry-fleshed and (2) the moist-fleshed. Dryness or moistness of the flesh after cooking is due primarily to the type of starch stored in the roots. The dry-fleshed types

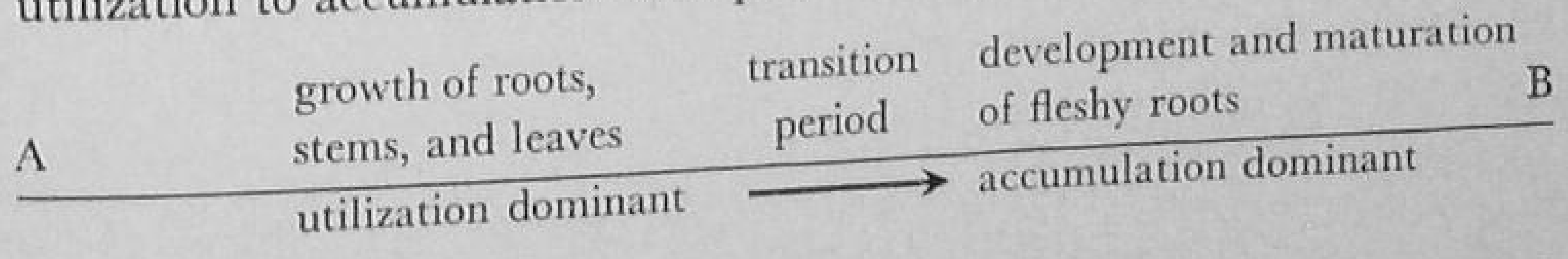
make a kind of starch which is less sticky and less hydrophilic than the kind of starch made by the moist-fleshed types. The dry-fleshed types are grown principally in the northern part of the sweetpotato belt, and the moist-fleshed types are grown mostly in the southern part. Both types store carotene in the roots; hence, color of the flesh is important.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal climatic factor is temperature. The sweetpotato is primarily a high temperature crop. In fact, authorities state that no other vegetable crop will stand more heat and few crops require as much. On the other hand, all parts of the plant are particularly sensitive to low temperatures. Below 48° F. the leaves turn yellow and the plant dies. At 48° F. the leaves remain green but the plant does not grow. Even a slight touch of frost kills the vines, and exposing the fleshy roots to temperatures at or below 40° F., even for a short time, greatly lowers their keeping quality and plant-producing capacity. Surveys have shown that present day varieties grow best in regions where the mean summer temperature is from 70° to 75° F., and the frost-free growing period is 150 days or more. Thus, these high temperature requirements and sensitivity to low temperatures explain why sweetpotatoes are grown in the southern regions of the country.

Soils. Most authorities agree that sweetpotatoes, particularly the varieties grown for table stock, thrive best on relatively infertile, well-drained, moderately to slightly acid, sandy loams underlaid with clay. Heavy or highly fertile soil generally produces roots of poor color and quality and induces excessive vine growth. To control soil rot, a serious disease in some districts, the pH of the soil is maintained between 5.5 and 6.0.

Disposition of the Carbohydrates. Suppose line AB represents a growing period of at least 150 days. During the first part of the period the plant develops its system of absorbing roots and stems and leaves. During the later stages of growth the plant develops its fleshy roots. Between these two periods there is a gradual transition from the development of the absorbing roots and tops to the development of the fleshy roots. Consequently, utilization is dominant during the first stages of growth, accumulation is dominant during the later stages, and a gradual transition from utilization to accumulation takes place during the intermediate stage.



Growing the Plants. In home and commercial gardens sweetpotatoes are propagated asexually by means of plants called "sprouts," "slips," or "draws," and by vine cuttings. Propagation by plants consists of treating roots of high yielding hills of improved strains of the recommended variety with corrosive sublimate, Semesan Bel or borax and bedding them in sandy loam. Bedding* of the roots is done in hotbeds and sources of heat are electricity, coal, wood, or manure. The optimum temperature for raising the plants varies from 75° to 85° F., and under favorable conditions the plants begin to appear from 7 to 10 days after the roots are bedded. Propagation by vine cuttings consists of taking parts of vines, 12 to 18 inches long, from plants growing in the field and which were originally raised in a propagation bed.

Transplanting and Cultivation. Plants are set by hand or by transplanting machines. At present by far the greater portion of plants are set by hand. Spacing in the row varies with the variety and type of enterprise. Table stock varieties are set from 10 to 18 inches apart and starch and feed varieties are set from 18 to 24 inches apart. Spacing between rows depends largely on the amount of drainage required. To attain good stands, the plants are watered immediately after transplanting. In general, nutrients are applied in the form of complete mixtures. In most sections of the sweetpotato belt complete mixtures high in potash are used. Applications vary from 500 to 1500 pounds per acre. Figure 127 shows a sweetpotato harvesting scene in Louisiana in 1949.

Harvesting, Storing, and Marketing. The fleshy roots are harvested when they attain proper size. Harvesting operations consist of: (1) Cutting the vines, (2) plowing out the rows, (3) scratching out the roots, and (4) grading the potatoes into containers for storage or market. Immediately after the harvest the potatoes are cured. As previously stated, the prime purpose of curing is to heal the bruised surfaces and to thicken the periderm or skin. Investigations have shown that healing of the wounds and thickening of the skin proceeds most rapidly at temperatures from 80° to 85° F. combined with 80 to 85 per cent humidity. In cool weather growers supply heat artificially and the practice is called curing. The period of curing depends largely on the weather, usually from 5 to 10 days. In general, the lower the temperature at the time of the harvest, the longer is the

*In southern Louisiana and southern Mississippi the roots are bedded in open fields.

FIG. 127. A sweetpotato harvesting scene in Louisiana. The ventilated crates are also used for storage and shipping. (Courtesy, J. A. Cox, Louisiana Agricultural Extension Service.)

period of artificial curing. Optimum storage temperatures are from 52° to 58° F. combined with 80 to 85 per cent humidity.

Sweetpotatoes are marketed in bushel baskets or bushel crates. Recently the Louisiana or James crate has become popular in some districts. The fleshy roots are placed on the various markets every month of the year. The Coachella Valley of California and the Mobile Bay district of Alabama ship during July. Louisiana, Virginia, Texas, Tennessee, North Carolina, and South Carolina ship from August to April and May. Delaware, Maryland, and New Jersey ship from September to May.

Questions

1. Distinguish between the moist-fleshed and the dry-fleshed types of sweetpotatoes.
2. Highly colored roots are more desirable for human consumption than poorly colored roots. Explain.
3. Only roots from high producing yields should be saved for "seed." Explain.
4. Soils containing abundant nitrogen make for abundant vine growth and low yields of poorly colored roots. Explain.
5. Abundant rainfall during the later stages of growth is likely to crack sweetpotatoes. Explain from the standpoint of outgo and income of water.
6. During the harvest sweetpotatoes should be handled carefully. Explain.
7. What is the prime purpose of curing? Give reasons for your answer.

8. Sweetpotatoes cure best at temperatures varying from 80° to 85° F. with high humidity. Explain.
9. Sweetpotatoes lose moisture in curing. They do not decrease in percentage of moisture content. Explain.
10. Growers who store potatoes in banks frequently say they secure excellent results one year and poor results another. Give your reasons.

21

Vegetable Crops Grown for Their Fruit and/or Seed

Assignment 29

Crops grown for their fruit and/or seed are the Solanaceous crops, the vine crops, sweet corn, okra, and the vegetable legumes. The Solanaceous crops are tomatoes, peppers, and eggplant. These plants belong to the Nightshade family and they have similar climate, soil, and cultural requirements.

THE SOLANACEOUS CROPS

Tomato

PLANT CHARACTERISTICS

Root System. The young seedlings develop a taproot and a subordinate system of lateral branches. When plants are transplanted the taproot is destroyed, the laterals become thick and well developed, and adventitious roots arise from the stem located below the surface of the land. In adult plants, the lateral and adventitious roots extend horizontally from 3 to 5 feet. Thus, the tomato develops an extensive root system.

Stems and Leaves. The plant develops a main stem and a system of lateral branches. In all commercial varieties the main stem is erect for the first 1 to 2 feet of growth when it becomes decumbent. In some varieties the stems extend for a small number of nodes only—the so-called determinate sorts; in others they elongate throughout the entire growing sea-

son—the so-called indeterminate sorts. The leaves are alternate, compound, relatively large, well developed, with rather broad leaflets in some varieties, and rather long narrow leaflets in others. They possess glandular hairs, which when disrupted liberate the odor and stain characteristic of the tomato plant.

Flowers, Fruit, and Seed. The flowers are borne in clusters on the main axis and on lateral branches. The number of clusters varies from 4 to 100 or more depending on the type and variety. Individual flowers contain a green calyx, a sulfur yellow corolla, five or more stamens, and a single superior pistil. They are mostly self-pollinated. The ripe fruit is a comparatively large, juicy, and fleshy ovary. According to the variety it varies in size (4 to 12 ounces), shape (oblate, globular, or flattened), color (yellow, pink, or red), cell number (5 to 25), and arrangement of cells (regular or irregular). The juice contains moderate quantities of soluble sugars, several organic acids and mineral salts, and relatively large quantities of vitamin C. The seed are imbedded in a jelly-like mass of tissue containing large quantities of phosphorus. They are relatively small and are covered with a mass of fine hairs. Under favorable conditions the seed germinates in a short time—from 2 to 4 days.

ECONOMIC IMPORTANCE AND DISTRIBUTION

The tomato is the third most important vegetable crop. It is ranked only by the potato and sweetpotato. It is grown in most home gardens to supply the needs of the family; in most market gardens and many greenhouse establishments to supply the needs of local markets; in the winter garden areas of the southern regions for long distance shipment; and in the Northeast, Southeast, and Pacific Coast regions for canning. Principal market garden areas are located near large cities such as New York, Philadelphia, Boston, Detroit, Chicago, and Los Angeles. Principal winter garden areas are: east Florida near Miami, west Florida, the Rio Grande Valley and Jacksonville of Texas, the Imperial Valley and Los Angeles of California, the Crystal Springs of Mississippi, the Humboldt of west Tennessee, and the Swedesboro of New Jersey. Principal canning sections are located in southern Indiana, the Sacramento and Santa Clara Valleys of California, the eastern shore of Maryland, southern New Jersey, northern Virginia, and southeastern Missouri.

Types. Modern varieties of tomatoes are descended from plants which produced large, oblate, rough, and ribbed fruit. These varieties lack this roughness and ribbing. In general, they are classified according to the

length of time the fruits become mature. There are three main groups: (1) Early, (2) midseason, and (3) late. Under favorable conditions early varieties mature fruit in 55 to 70 days and produce relatively low yields; midseason varieties mature fruit in 66 to 80 days and produce moderately high yields; and late varieties mature fruit in 73 to 100 days and produce high yields. Special varieties have been developed for greenhouse culture.

GROWTH AND DEVELOPMENT

Climatic Requirements. The principal environmental factors are temperature combined with light intensity. Surveys have shown that present day varieties produce the highest yields in regions characterized by a mean summer temperature of approximately 73° F. combined with moderate light intensity. In the humid section of the United States this mean temperature occurs in southern Indiana, southern Ohio, eastern Maryland, and New Jersey. In regions south of this section the high summer temperatures combined with the high light intensity induce a high transpiration rate. Under these conditions the outgo of water frequently becomes greater than the income, a water deficiency exists within the plant, the blossoms drop off and, as a result, the yields are low. Furthermore, certain diseases are most prevalent. In regions north of this section the mean summer temperature is lower than 73° F. and the frost-free growing season is comparatively short.

Soils. The tomato is grown on many soils. Where earliness of maturity of the fruit is important, well-drained sandy loams are preferred. Conversely, where earliness is not important and large yields are essential, clay loams and silt loams are used. In both cases the soil should be well drained and slightly acid.

Disposition of the Carbohydrates. The life of the tomato plant may be divided into two more or less distinct and overlapping stages: (1) The seedling and (2) the fruiting. The seedling stage begins with germination and continues until the first blossoms are formed and the fruiting stage consists of the remainder of the life of the plant. During the seedling stage the plant develops stems, leaves, and roots only, and during the fruiting stage the plant develops stems, leaves, and roots simultaneously with flowers and fruit. Thus, the utilization of carbohydrates is dominant during the seedling stage and very little dominance of both utilization and accumulation takes place during the fruiting stage.

The tomato is very sensitive to the environment in which it grows. For example, abundant nitrogen plus abundant moisture, plus temperatures

on the upper half of the optimum range, plus maximum opportunity for carbohydrate manufacture, make for abundant vegetative growth and little fruitfulness. This is another way of saying that vegetation is dominant over reproduction. On the other hand, moderately abundant nitrogen, or moderately abundant water, or a relatively low temperature plus maximum opportunity for carbohydrate manufacture, make for moderate vegetative growth and abundant yields. Consequently, the grower should maintain a fairly even balance between vegetative and reproductive processes to obtain maximum yields. Suppose line AC represents a growing period of 120 to 150 days.

A	growth of stems and leaves	→	growth of stems and leaves, and flowers and fruit	C
	utilization dominant	B	utilization and accumulation processes proceeding simultaneously	

Line AB represents the production of stems and leaves during the first period of growth. Line BC represents the fruiting period during which leaves and stems, and flowers and fruit are being produced simultaneously.

PRINCIPAL CULTURAL PRACTICES

Growing the Plants. Methods of growing the plants differ with the locality. Market gardeners in the Midwest and Northeast, because they are interested in early production and because of a short period of favorable weather for the growing of tomatoes outdoors, raise the seedling plants in greenhouses, hotbeds, and cold frames. When the weather is favorable they set these plants out in the garden or field. Truck crop growers in the Southeast, if they are interested in early fruit production, also use hotbeds and cold frames. However, if they are raising plants for shipment North they use open beds and fields. Millions of tomato plants are shipped North each spring.

Transplanting. The student will recall that tomato plants recover rapidly from the check in growth incident to transplanting. There are two reasons for this relative rapid recovery. Suberization takes place relatively late in the region of water and nutrient absorption, and the plants possess the ability to store starch in their tissues. This reserve carbohydrate is used to develop a new root system. In commercial operations the plants are usually transplanted with water. The water settles the soil around the roots

and is available for absorption. Recent tests indicate that the application of readily available nutrients in solution with water facilitates recovery more rapidly than the application of water alone.

Nutrition. The development of blossoms and fruit is associated with moderate vegetative growth, carbohydrate accumulation, and the production of flower-forming hormones. If vegetative growth is vigorous and rapid, carbohydrate accumulation and flower hormone production is low and, as a result, very few, if any, blossoms are formed. In other words, the development of the blossoms is dependent on a supply of carbohydrates and other substances over that used for the development of stems, leaves, and roots and for respiration. With other factors of the environment favorable for growth the nutrient supply, particularly the nitrogen supply, determines the type of growth the plant will make. Since moderate vegetative growth is necessary, particularly when the first blossoms are developing, and since the plant requires abundant nutrients during the fruiting period to develop the numerous seeds in the fruit, the nutrient supply should be applied accordingly.

In practically all producing districts complete mixtures are necessary for the nutrition of the tomato. In most of the winter garden areas of the South 1–1½–1 and 1–2–1 ratios are used, and in the Midwest 1–3–1 and 1–4–1 ratios are necessary. Within any particular region the method of application and the amount of nutrients necessary depend largely on the soil type, previous fertilization, and intensiveness practiced.

Marketing. Tomato fruits are harvested for the market in various degrees of maturity. These degrees of maturity are green-mature, turning, pink, hard ripe, and ripe. They are indicated as follows: Green-mature—the fruit has attained its full size but the development of pigment is not apparent. Turning—the red pigment is evident at the blossom end. Pink—most of the surface of the fruit is pink. Hard ripe—the entire surface of the fruit is red or pink and the flesh is firm. Ripe—color is fully developed and the fruit is somewhat soft.

Fruit raised in the winter garden areas of the South are generally picked in the green-mature, turning, or pink stages and are packed in small flat containers called lugs. Fruit produced by market gardeners are picked when hard ripe and are packed in various types of baskets. Fruit raised for the cannery are picked in the ripe stage of maturity. In general, fruit ripened on the vine are higher in sugars, organic acids, and vitamin C than those picked in the green-mature stage. Note the harvesting scene of fruit grown for the cannery in Figure 128.

Fig. 128. Harvesting of tomatoes grown for the cannery in Indiana.

Pepper

Plant Characteristics. In bearing plants the root system is moderately extensive. The main axis is erect, woody at the base, and much branched. The leaves are flat, shiny, simple, and entire. The flowers occur singly in the axils of the leaves. They are both self- and cross-pollinated and have white or purple petals, five stamens, and a single superior pistil. The fruit is a moderately large, fleshy ovary, dark green when immature, and red or yellow when mature according to the variety. The outer wall is fleshy and thick, and the inner walls bear placenta which in turn bear seeds. Both green-mature and mature fruits are high in carotene, the B vitamins, and in ascorbic acid. The seed are flat and disk-shaped and require a fairly high temperature (70° to 75° F.) for prompt germination.

Economic Importance and Distribution. There are two types of peppers: (1) Sweet and (2) hot or pungent. The sweet peppers are relatively large and are eaten fresh or cooked. The hot peppers are moderately small and are used for canning, for the making of paprika, or for the making of chili sauce. Sweet peppers are raised in home gardens and in commercial gardens for local and for long distance markets. Commercial areas exist in Florida, New Jersey, and Texas. Peppers for canning are raised in Georgia, Texas, and California. Peppers for paprika are raised in Loui-

siana, and peppers for chili sauce are raised in Mexico and California. Note the field and shape of the pimiento pepper shown in Figure 129.

Eggplant

Plant Characteristics. Eggplants develop a moderately extensive root system. Like the pepper the main stem of mature plants is woody at the base and is much branched. The leaves are simple, alternate, large, somewhat angled or lobed. The flowers occur singly or in clusters opposite the leaves. They are moderately large, hermaphroditic, violet or purple, and mostly self-pollinated. The fruit is a fleshy ovary varying in size (3 to 6 inches in diameter), shape (long, ovate, or pyriform) and color (dark purple, light purple, yellowish, striped, and white), according to the variety. Figure 130 shows fruit of Black Beauty, a widely adapted variety.

Growth and Culture. The eggplant is used in the fresh state only. Commercial areas for long distance shipment exist in Florida and Louisiana. Two distinct types are grown: (1) Varieties which develop large, dark purple fruit and (2) varieties which develop small, light purple fruit. The type of growth, soil, environment, and culture requirements are essentially the same as those for the tomato and pepper.

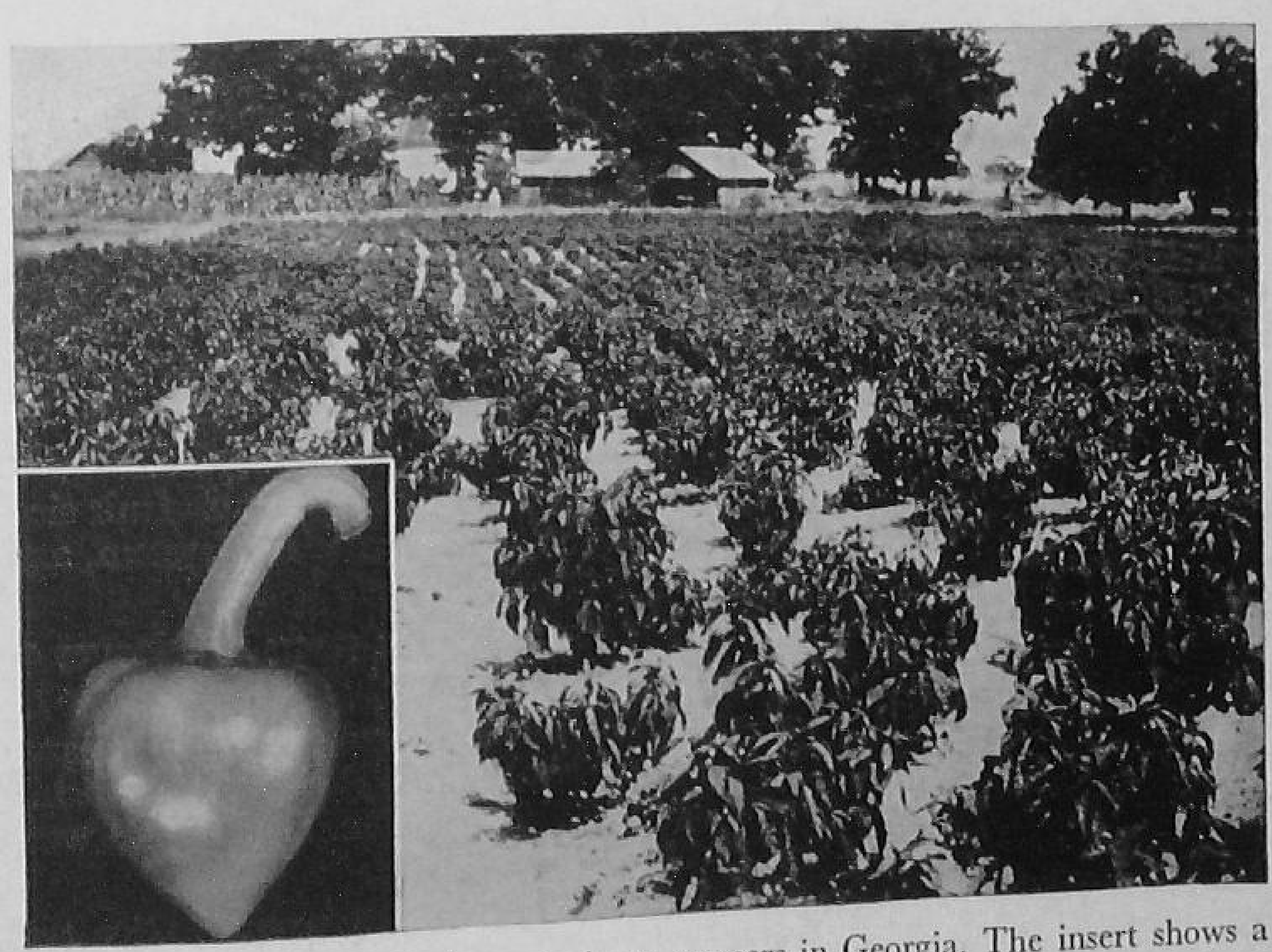


Fig. 129. A field of Truhart pimiento peppers in Georgia. The insert shows a near perfect fruit of this variety. (Courtesy, W. H. Greenleaf, Alabama Agricultural Experiment Station.)

FIG. 130. Black Beauty eggplant. (Courtesy, Associated Seed Growers, New Haven, Connecticut.)

Questions

1. Tomatoes growing in old barnyards are frequently overvegetative and non-fruitful. Explain.
2. Tomatoes started in the greenhouse in February require lesser quantities of nitrogen than those started in August. Explain.
3. Tomatoes growing on sandy loam produce lesser yields than those growing on clay loams. Explain.
4. Important canning states are Indiana, New Jersey, and Maryland. Give reasons.
5. In the extreme South and the extreme North yields are relatively low. Explain.
6. Pruning tomatoes reduces yields per plant, usually increases fruit size, increases blossom-end rot, limits the extension of the root system, and permits close planting. Explain fully.
7. What are: the similarities and differences in the stems and leaves of the tomato? the pepper? the eggplant?
8. Given two pepper patches of the same variety growing on the same farm. Patch A is growing on bottom land; patch B is growing on hill land. Plants in A were bushy, big, and fruited late. Plants in B were non-bushy, small, and fruited early. Explain fully.
9. The tomato is more popular than the eggplant or pepper. Give two reasons.

THE VINE CROPS

The vine crops are cantaloupes, cucumbers, pumpkins, squash, and watermelons. These crops have similar climatic, nutrient, and cultural requirements and are attacked by the same insects and diseases.

COMMON PLANT CHARACTERISTICS

Root System. The vine crops possess very extensive, shallowly penetrating root systems. During the first stages of growth root development is relatively rapid. When the vines begin to run (at this stage they are from 12 to 18 inches long) most of the lateral roots are longer than most of the stems. As the vine continues to grow, the lateral roots continue to grow also. Thus, in mature plants the lateral roots extend far beyond the main or lateral stems. From the nature of the development and position of the root system an intelligent cultivation program can be formulated.

Stems and Leaves. The stem system consists of a main axis and a series of primary and secondary laterals. In adult plants the branches are long and trailing. Consequently, each plant requires a large area of land and planting distances are quite wide. To supply the plant with large quantities of water, the extensive root system is necessary. In addition, the many leaves present a large transpiring surface. Thus, under conditions of rapid transpiration the amount of water lost is large. The leaves are alternate, simple, long petioled, and palmately veined. Tendrils are formed opposite the leaves. These tendrils twine around objects and help to anchor the vines to the surface of the land.

Flowers, Fruit, and Seed. The vine crops are monoecious and andromonoecious. The monoecious crops develop flowers of one sex only. Both male and female flowers occur on the same plant. Andromonoecious crops develop hermaphroditic and staminate flowers on the same plant. In all cases the flowers are axillary and develop a moderately large yellow corolla. These crops are wholly insect-pollinated, the honeybee being the principal carrier. The student will recall the discussion on the effect of temperature and wet weather on the activity of honeybees in the orchard. In like manner, if bees are inactive in cucumber, cantaloupe, squash, pumpkin, and watermelon fields yields are likely to be low.

The fruit is an enlarged fleshy structure consisting of ovary, the inner portion, and receptacle, the rind. The seed is relatively large, elliptical, with a hard coat. Under favorable conditions the seed germinates in from 2 to 5 days.

Disposition of the Carbohydrates. The life cycle is divided into two stages: (1) The seedling and (2) the blossoming and fruiting. As with other crops, the seedling stage begins with germination and ends when the first blossom develops. The fruiting stage begins when the first blossoms are produced and ends when the last fruit has matured. Like the tomato, pepper, and eggplant, during the seedling stage the plants are developing roots, stems, and leaves, and during the fruiting stage they are developing roots, stems, and leaves simultaneously with the development of flowers and fruit. Thus, carbohydrates made during the seedling stage are utilized for root and top growth, and the carbohydrates made during the fruiting stage are used both for the development of root, stems, leaves, flowers, and fruit.

Suppose line AC represents a growing period of 100 to 180 days. Line AB represents the period of stem and leaf growth only. Line BC represents the period when stems and leaves, and flowers and fruit are produced simultaneously.

A	growth of stems, leaves and roots	B ⟶	growth of stems, leaves and roots, and flowers and fruit	C
	utilization dominant		utilization and accumulation taking place together	

The student should remember that the length of the seedling stage varies with the crop. For example, in average weather cucumber varieties for pickling will begin to produce fruit from 40 to 50 days after the seed are planted, while watermelons require from 80 to 100 days to produce the first fruit.

Cantaloupe

The leaves are simple, alternate, and palmately lobed. The fruit varies in size, shape, degree of ribbing and netting of the rind, color, texture, and sweetness of the flesh.

Economic Importance and Producing Centers. The cantaloupe is the most valuable vegetable crop belonging to the cucumber family. In general, there are two types: (1) The netted and (2) the winter. Netted melons have a netted skin, shallow sutures and ribs, loose textured flesh, and keep for a short time in storage. On the other hand, winter melons have a smooth or ridged skin, firm textured flesh, and keep for a long time in storage. Of these types the netted is the more important commercially. Important commercial districts are: (1) The early, west coast of Mexico,

Imperial Valley of California, and Rio Grande Valley of Texas; (2) the intermediate, Salt River Valley of Arizona, Tulare district of California, winter garden region of south Texas, and Edisto River Valley of South Carolina; and (3) the late, eastern shore of Maryland, Delaware, southern Indiana, northern Arkansas, and southwestern Michigan.

CULTURE

Starting the Plants. The seed is planted directly in the field or in plant containers in greenhouses, hotbeds, or cold frames. Planting seed directly in the field is generally practiced in the southern half of the United States. Since soil temperatures below 50° F. prevent germination, and warm soil temperatures varying from 65° to 75° F. facilitate rapid germination, field planting is delayed until the soil is warm and all danger of cold weather is passed. Usually from six to ten seeds are dropped in each hill, and the seedlings are thinned to two plants per hill. The hills are 3, 4, or 5 feet apart depending on the variety and the locality. The planting of seed in plant containers and growing the seedlings in plant growing structures is practiced in northern United States where the frost-free growing season is relatively short. Transplanting to the field is usually done as soon as the weather is warm and all danger from frost is passed. At this time the plants are usually 3 to 4 weeks old. Because a layer of suberin develops in the absorbing system at an early age in the life of the roots, the plants are transplanted carefully and are raised in containers. In this way, injury to the root system is reduced to a minimum.

Marketing. In general, the fruits are picked when they are mature. At this stage of ripeness they have attained their highest quality, flavor, and edibility. An accurate measure of quality and flavor is the percentage of total solids in the juice of the fruit. Investigations have shown that the percentage of total solids is positively associated with sugar content, flavor, and edibility. In other words, melons with a high total solid content (9 to 10 per cent or more) possess a higher percentage of sugars and are sweeter than melons with a low percentage of total solids. At present, the percentage of total solids in the juice is used as a standard test for determining maturity of cantaloupes in many producing districts.

Promptness in picking, hauling to the packing shed, grading and placing the fruit under comparatively low temperature is essential, since a high respiration rate will rapidly deplete the sugars in the fruit. To provide necessary ventilation cantaloupes are usually packed in crates with solid ends and slatted sides. Various sizes are used.

The leaves are simple, alternate, and angular. The staminate flowers occur in clusters and the pistillate flowers occur singly or occasionally in groups of two or more. The female flowers may be distinguished from the male flowers by the young ovary located back of the petals. Under field conditions the male flowers appear 1 to 2 weeks before the first female flower and are produced in greater numbers than the female flowers. Since the blossoms and fruits are borne in the leaf axils, continuous growth of the stems and leaves is necessary for high yields. In general, the fruits are elongated or cylindrical. They vary in size (long, moderately long, and short), color of the rind (light to dark green) and color of the spines (white or black).

Economic Importance and Producing Centers. In the United States two distinct industries exist: (1) The slicing and (2) the pickling. Distinct adapted varieties have been developed for each industry. Varieties for slicing produce long cylindrical, dark green fruits with crisp flesh, and varieties for pickling produce small fruits which are adapted for preservation in salt brine.

The Slicing Industry. Three more or less distinct slicing industries exist: (1) Growing in the greenhouse, (2) growing in cold frames, and (3) growing in open fields. Most of the greenhouse forcing establishments are located in or near the large cities of the North. Fall, winter, and spring crops of cucumbers are grown in rotation with other greenhouse vegetable or flower crops. Special varieties adapted to greenhouse culture have been developed. Cucumbers grown in cold frames are started in greenhouses or hotbeds and the transplants are removed to the frames. These cold frames are in turn removed when picking begins. This method of culture is used principally in the Norfolk district of Virginia. Cucumbers grown for slicing in open fields are raised in the trucking districts of the Southeast and Southwest. In these regions the climate, soil, and transportation facilities make possible the production of fruits for long distance shipment from March to July. Principal producing districts are: central Florida, southern Texas, southeastern South Carolina, eastern North Carolina, and the Norfolk section of Virginia. In general, the cucumbers are raised on well-drained, slightly acid, fertile sandy loams and loams.

The Pickling Industry. Cucumbers for pickling are raised in open fields. Seed is usually planted in rows 5 or 6 feet apart, and the seedlings are thinned to stand from 12 to 18 inches apart in the row. Harvesting usually

FIG. 131. A field of cucumbers grown for pickling in south Mississippi. (Courtesy, W. S. Anderson, Mississippi State College.)

begins from 6 to 8 weeks after the seed is planted. For the continuous production of fruit, harvesting is thorough and systematic. If an undersized fruit is allowed to remain on a vine, yields of that vine will be reduced. The fruits are usually graded into two or three sizes and delivered to the salting station for preservation in brine.

Principal producing districts are located in the southern Peninsula of Michigan, Wisconsin, Indiana, Ohio, and southern Mississippi. Districts producing lesser quantities are located in Virginia, New York, North Carolina, Illinois, and California. Figure 131 shows a field of cucumbers grown for pickling, near Wiggins, Mississippi.

PUMPKIN

Pumpkins belong to two botanical species: *Cucurbita pepo* and *Cucurbita moschata*. Varieties of *Cucurbita pepo* are divided into two groups: (1) Those which develop short erect stems and mature their fruits in a relatively short time, and (2) those which develop long, 6 to 20 feet, trailing stems and mature their fruits in a relatively long time. Both groups have prickly, harsh textured, deeply notched leaves, and a five-sided longitudinally grooved fruit stalk. Varieties of *Cucurbita moschata* develop long trailing stems, soft textured leaves, and a five-sided indistinctly grooved fruit stalk. In addition, these varieties develop white spots at the junction of the veins of the leaves. Varieties of both types are usually monoecious. The staminate flowers have long slender stalks, and the pistillate flowers have short thick stalks. Both are axillary and occur singly.

The fruiting habit is similar to that of the cantaloupe. Like the cantaloupe, there are periods of fruit setting alternated by periods of female flower abortion. Like other members of the cucumber family, honeybees are the principal agents of pollination. The fruits are fleshy and vary greatly in size, shape, and color. Carbohydrates are stored in comparatively large quantities, and the yellow-fleshed varieties contain carotene.

Types and Culture. As stated previously, pumpkins are divided into two types: (1) The bush and (2) the trailing. With the bush type, the fruits are usually harvested when immature, and the cultural requirements are practically the same as for cantaloupes. With the trailing types, the fruits are harvested when fully mature. Mature fruits are high in sugars and keep well in storage. The cultural requirements are the same as for the watermelons.

Squash

Squash belongs to one botanical species only, *Cucurbita maxima.* The plants have long trailing stems and smooth soft textured leaves. The fruit stalk is round, soft, and spongy. The fruits are large and fleshy and contain large quantities of carbohydrates. Cultural requirements are practically the same as for the growing of watermelons.

Pumpkins and squash are grown for fresh consumption, for canning, and for drying. The fresh product is grown in home and market gardens. The product for canning and drying is grown chiefly in California.

Watermelon

The stems are angular in cross section and the leaves are divided into three or four lobes. The flowers occur singly in the axils of the leaves and usually open at sunrise and close on the afternoon of the same day. As with other members of the cucurbits, the principal agent of pollination is the honeybee. According to the variety, the fruits vary greatly in size (5 to 40 pounds), shape (round, oval, oblong, or cylindrical), color and shipping ability of rind (white, black, mottled, or striped), and in color and sweetness of the flesh.

Economic Importance and Producing Regions. The watermelon has been grown in the United States since about 1600. To supply the various markets at present, watermelon farmers produce from 70 to 80 million melons per year. The principal commercial districts are located in the Southeast and Southwest: southern Georgia, southeast Texas, northern Florida, southeastern South Carolina, southern Alabama, and eastern

FIG. 132. A Black Diamond watermelon field in south Georgia in July, 1949. (Courtesy, Otis Woodard, Georgia Coastal Plain Experiment Station.)

North Carolina. Figure 132 shows a field of watermelons in south Georgia in 1949. Note that vines have been placed over the fruit to prevent sun scald.

Marketing. Market requirements vary. Some markets require an elongated fruit; others a somewhat round fruit. Some markets demand relatively small melons; and others require relatively large melons. If your section raises watermelons for long distance shipment, study the characteristics of the main variety, particularly from the standpoint of color of flesh and seed, shipping ability of the rind, and texture and quality of the flesh. Does your community ship a standardized product?

Questions

1. Distinguish between: netted melons (cantaloupes); winter melons.
2. Outline a cultivation program for cantaloupe culture for your region.
3. If the weather is cold and wet during the blossoming season, very little pollination is likely to take place. Explain.
4. Given two cucumber plants. On plant A two fruits are allowed to remain on the vine until they are ripe; on plant B all fruits are picked while immature. Which plant produces the greater number of fruits? Give reasons.
5. Non-systematic, careless harvesting of pickling and slicing cucumbers will reduce yields. Explain.
6. In general, abundant water and moderate supplies of nutrients are necessary throughout the fruiting period. Explain.

7. In the British Isles cucumbers and cantaloupes are raised entirely in plant growing structures; in northern United States the seedlings are raised in plant growing structures and transplanted to the field; and in southern United States they are raised entirely in the field. Explain.
8. Watermelon fruits are not harvested until they are ripe. Explain.
9. In general, fruit should be picked in early morning. Explain.
10. Given two watermelons. Melon A was exposed to sunshine for 4 hours after picking; melon B was kept in shade. Which watermelon would you prefer? Give your reasons.
11. Ripe melons from healthy vines remain sweet if kept on ice. They lose their sweetness if kept in a warm room. Explain.
12. Differentiate between: pumpkins; squashes.

SWEET CORN

Plant Characteristics

Root System. The root system consists of two parts: (1) The absorbing and (2) the buttress. The absorbing roots are adventitious and very extensive. Investigations have shown that the roots of mature plants have a lateral spread of 4 to 5 feet and a vertical spread of 6 to 8 feet depending on soil conditions. The buttress roots arise from the first or second nodes above the soil in the form of a whorl. They proceed outward and downward and penetrate the soil, thus providing for additional anchorage and wind resistance and additional absorbing roots.

Stems and Leaves. The stem system consists of primary stems and secondary stems. The secondary stems are frequently called suckers. Under field conditions the primary stem bears the staminate and pistillate inflorescences, and the secondary stems may or may not bear flowers. An individual leaf consists of three distinct parts: (1) Sheath, (2) ligule, and (3) blade. The sheath is the basal portion of the leaf which is wrapped around the stem; the ligule is attached to the top of the sheath and fits tightly around the stem; and the blade is comparatively long, parallel veined, and pointed.

Flowers and Fruit. Sweet corn is monoecious. The staminate inflorescence contains a large number of small flowers, terminates the primary stem, and is called the tassel. Each staminate flower has three stamens and a rudimentary pistil. The pistillate inflorescence also contains a large number of flowers, terminates a short lateral, and when mature is called the ear. The internodes of each lateral are very short. Thus, the sheaths of the leaves overlap and form the husk of the ear. Each pistillate flower has a single pistil and rudimentary stamens. The ovary is the immature kernel and the style is long and branched near the tip. These styles are called the

"silk" and protrude through the top of the husk to catch pollen grains which are carried by gravity or wind. Corn is mostly cross-pollinated.

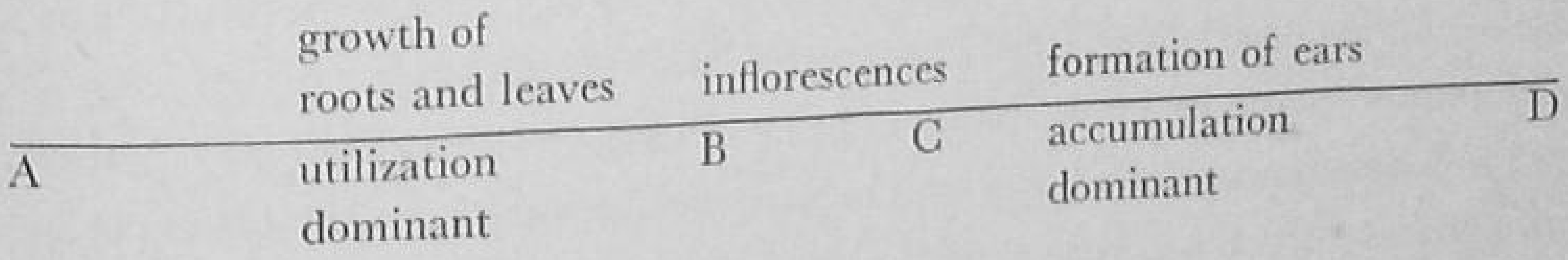
Growth and Development

Climatic Requirements. The principal climatic factors are temperature and the water supply. In common with many other crops, temperature has a marked effect on the growth of sweet corn. Investigations have shown that the higher the temperature between 50° and 90° F., the greater is the rate of growth and the shorter is the time necessary for the plant to attain a particular stage of maturity. Thus, the higher the temperature, within these limits, the shorter is the time from the seedling stage to tasseling, or from the premilk to the canning stage of the kernels.

A uniform moisture supply is necessary for rapid growth and development. If the moisture supply is low and the weather is hot, water deficits take place, the manufacture of food declines, and yields are low.

Soils. Sweet corn is grown in a wide variety of soils. Growers for early market usually plant on well-drained, sandy loams. Growers for the late market or for the cannery usually select silt or clay loams or well-drained bottom land.

Disposition of the Carbohydrates. Sweet corn has the determinate type of growth, since the stem terminates with an inflorescence. Thus, the development of the stem, leaves, and roots is followed by the development of flowers and fruit. In other words, as with all plants with the determinate type of growth, vegetation and reproduction processes occur in succession. As previously stated, temperatures on the upper half of the optimum range, abundant water and nutrients combine to promote vegetative processes, and temperatures on the lower half of the optimum range, moderate water and nutrients combine to promote reproductive processes. Suppose line AD represents a growing period of 70 to 150 days. Line AB indicates the period of stem and leaf growth; line BC indicates the period of flower development; and line CD indicates the period of ear development.



Economic Importance and Distribution

Sweet corn is grown in home gardens for the use of the family; in market gardens for local markets; in certain trucking regions for long

distance shipment; and in fields for canning. The principal states supplying long distance markets are: Tennessee, Alabama, Florida, Georgia, and Mississippi. Principal canning states are: Illinois, Minnesota, Indiana, Ohio, and Maryland.

Types. Two types of sweet corn are grown: (1) Certain strains and varieties of field corn and (2) true sweet corn. Within the past decade many sweet corn hybrids have been produced. In general, these hybrids are more vigorous and disease-resistant and produce higher yields than the non-hybrids.

Principal Cultural Practices

Planting the Seed. The seed are planted by hand or by hand-operated or power-drawn planters. In general, market gardeners use hand machines, and canners or growers of large quantities use power-drawn machines. The seed is planted in hills or in drills. Each method of planting has advantages and disadvantages. The hill method permits cultivation in both directions and reduces the amount of hand hoeing. The drill method permits a more uniform distribution of plants and allows more space between plants than the hill method.

The rate of seeding depends on: (1) The time of planting, (2) the spacing, and (3) the variety. In general, the earlier the seed is planted, or the colder the soil, or the closer the spacing, the greater is the rate of planting. Ordinarily, field corn varieties require lesser rates of seeding than the true sweet corn varieties. This is true particularly if the weather is cold and wet at the time seeding is made. From 8 to 12 pounds of seed are usually required per acre.

Suckering. Suckering consists of removing the side shoots or secondary stems which grow from the base of the plant. In the early days of commercial sweet corn production, this practice was very common. Growers believed that suckering produced earlier and greater yields and larger ears than non-suckering. Recent experiments have shown that suckering decreases the total yield and does not appreciably increase the yield of the first harvest and the size of the ear. In addition, suckering markedly decreases the yield of the stover. How does suckering decrease yields? Suckering removes secondary stems. It, therefore, removes a certain amount of leaves. In other words, suckering reduces the leaf area for carbohydrate manufacture. The reduction in the leaf area reduces the amount of carbohydrates made, which in turn reduces the growth and yield. Figure 133 shows a field of mature plants of sweet corn in early spring in south

FIG. 133. A sweet corn field in the Lake Okeechobee district of south Florida in early spring 1949. The low-flying plane was used to keep birds from eating the corn. (Courtesy, R. V. Allison, Florida Agricultural Experiment Station.)

Florida. Since the development of adapted hybrids, sweet corn has become an important industry in many districts of the South.

Marketing. The ears are harvested when the kernels are in the milk stage. When the kernels are young and small, the juice is clear and watery. As they become larger, more plump, and older, the juice becomes milky and this is known as the milk stage. Finally, the juice becomes doughy and this is known as the dough stage. At the premilk stage the kernels are very sweet but they are also small and generally lack plumpness. At the milk stage they are also sweet but they have attained full size and plumpness. At the dough stage most of the sugars have changed to starch. Many growers have found that when the silks first become brown and the ears feel plump, the ears are ready to be picked. For long distance shipment the ears are packed in ventilated crates or in mesh bags and shipped during warm weather in refrigerated cars.

OKRA

Plant Characteristics

The root system is extensive, and the stem consists of an erect axis and primary laterals, which become woody with age. The leaves are ovate and lobed. The flowers are axillary, large, showy, and contain both stamens and pistils. The stamens form a column around the superior pistil. The flowers are both self- and cross (insect)-pollinated. The fruits are elongated, relatively large pods. They vary in color, degree of ribbing, and in pubescence according to the variety and are consumed in the immature state. When mature, the pods are hard and woody. The seed are

relatively large and dark in color. The optimum temperature for germination is from 80° to 86° F.

Growth and Development

Like the vine crops, the type of growth of okra is indeterminate. Thus, the life of the plant may be divided into two stages: (1) The seedling and

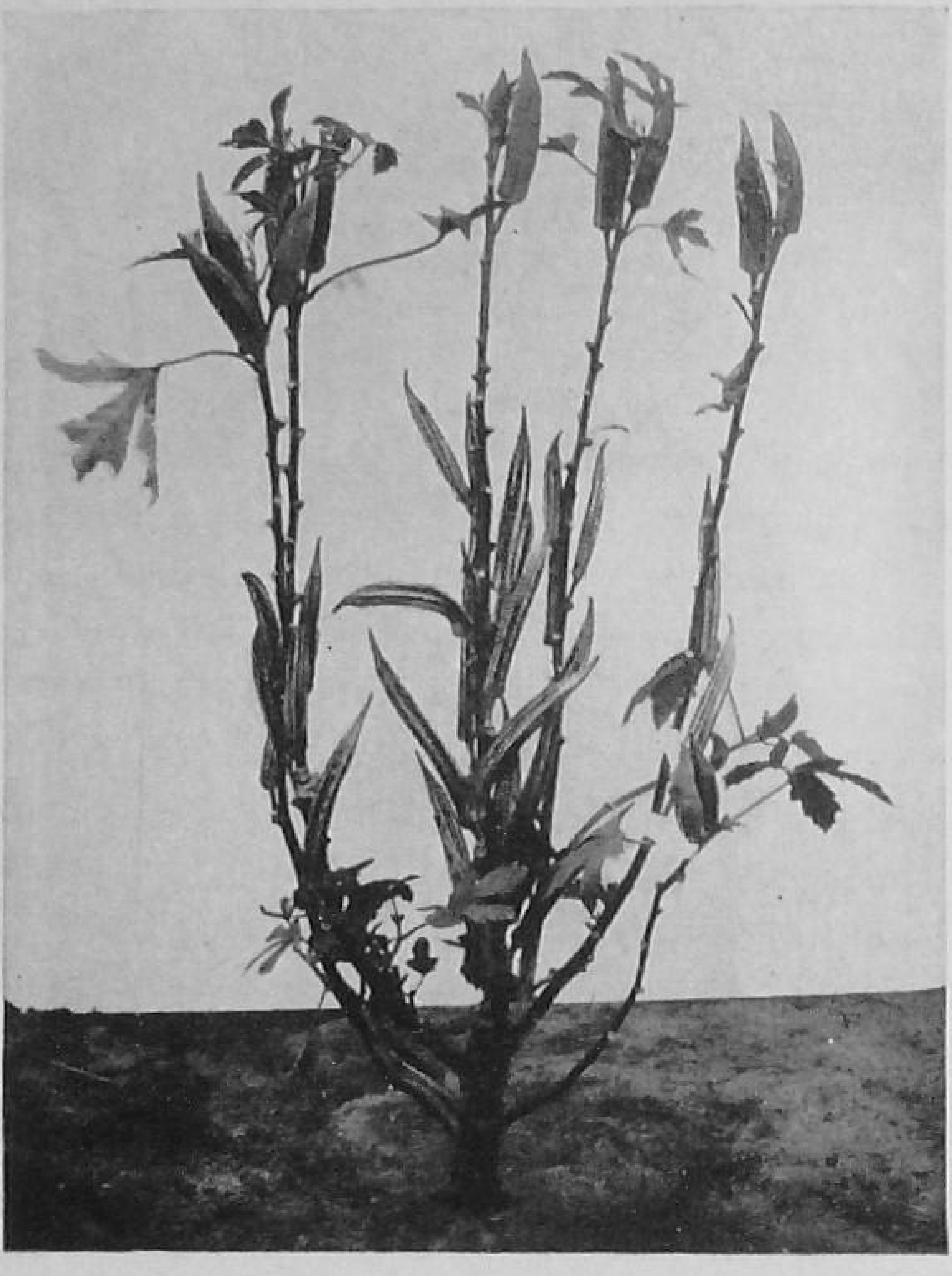


Fig. 134. Two cycles of fruit on Clemson Spineless okra. (Courtesy, R. A. McGinty, Clemson Agricultural College.)

(2) the flowering and fruiting. During the seedling stage the plant is developing roots, stems, and leaves and during the flowering and fruiting stage the plant is developing roots, stems, and leaves together with flowers and fruit. Scientists have found that there is a marked correlation between the growth of stems and leaves and the production of flowers and fruit. If the pods are allowed to mature, growth of stems and leaves is retarded. If they are harvested when immature, vegetative growth proceeds until the

plants are killed by frost. Thus, the harvesting of okra should be thorough and systematic. Note the cyclic development of the fruit of the plant in Figure 134.

Culture and Uses

Okra is grown in southeastern United States to a greater extent than elsewhere. In this region, because of its adaptation to high temperatures, it is a standard home garden vegetable. Limited quantities are grown for canning. The pods are used principally in soups and stews. They contain moderate quantities of carotene and thiamin. For large yields okra requires a long warm growing season. Consequently, larger yields are produced in the southern regions than in the northern regions. The seeds are usually planted in hills or in drills in rows 3½ or 4 feet apart, and the seedlings are thinned to stand about 12 inches apart for the dwarf varieties and 18 to 24 inches apart for the larger growing sorts.

The pods are harvested in the immature state usually when they are from 1 to 5 inches in length. At this stage the pods are young, tender, and crisp. During warm weather two or three pickings per week are necessary.

Questions

1. From the standpoint of human nutrition the yellow varieties of sweet corn are superior to the white varieties. Explain.
2. On self-mulching loams sweet corn need not be cultivated after it is half grown. Explain.
3. On sandy loams in New York tests have shown that removal of suckers (a type of pruning) has decreased yields. Explain.
4. In the home garden sweet corn should be planted in blocks—not in a single row. Explain.
5. Many true sweet corn varieties have loose husks, hence they are easily penetrated by the corn-ear worm. They are not adapted to the South. Explain.
6. Your mother wants to know how to harvest sweet corn so that it will remain sweet. Outline two methods.
7. For what is okra grown?
8. Okra is grown chiefly in the South. Explain.
9. For continuous fruit production a uniform nutrient and water supply is necessary. Explain.
10. Given two lots of okra. Lot A is harvested carelessly; marketable pods are missed by the pickers. Lot B is harvested carefully; marketable pods are not missed by the pickers. Which lot will produce the higher yields? Explain.

11. Given two lots of okra. Lot A was irrigated; lot B was not irrigated. A drought of 3 weeks occurred during the fruiting period. Which lot produced the greater yields? Explain.
12. Harvesting of the immature pods should be thorough and systematic. Explain.

VEGETABLE LEGUMES

The vegetable crop legumes are snap bean, lima bean, certain varieties of soybean, and cowpea and garden pea. As indicated, all of these plants belong to the legume family. All are warm-season crops with the exception of the garden pea, which is distinctly a cool-season crop.

COMMON PLANT CHARACTERISTICS

Root System. The root system consists of a taproot and extensively branched laterals. These laterals may extend horizontally from 1 to 5 feet. Thus, the root system is extensive and widespread. In common with other members of the legume family, the roots support the growth and development of nitrogen-fixing bacteria called *Rhizobium*. These bacteria possess the ability to use nitrogen from the air. This nitrogen is combined with sugars by the bacteria to form amino acids which are used by the bacteria and the bean plant. Unless the soil contains abundant quantities of an adapted strain of these bacteria, inoculation with pure cultures is generally advisable. Tests in Washington and Wisconsin, where large quantities of garden peas are grown, have shown that good strains of bacteria have increased yields growing on land which had previously been planted to peas. Growers often test the effect of inoculation by comparing the yield of treated and untreated strips planted side by side in the same field.

Flowers, Fruit, and Seed. The inflorescence is a raceme in the case of beans and cowpea and consists of single or two flowers in the case of garden pea. Individual flowers are moderately large and showy and possess the characteristics of the legume family. There are five sepals and five petals. The large upper petal is called the standard, the two lateral petals are called the wings, and the two lower petals are called the keel. The keel encloses ten stamens and a single pistil.

Both self- and cross-pollination take place. Honeybees and bumblebees possess the ability to enter the flowers and cause cross-pollination. The fruit is a one-celled, elongated pod called a legume.* The pod varies in

*The members of the legume family are not called legumes because their roots support the growth of *Rhizobium,* but because they produce a type of fruit called a legume.

shape (flat or round, straight or curved), length (2 to 8 inches or more), color (yellow, yellowish green, green, and dark green), and number of seeds (three to ten or more, depending on the kind of crop and variety). The seeds are relatively large, consist mostly of two well-developed seed leaves—the cotyledons—and are highly nutritious, since they contain large quantities of starch, proteins, and relatively large quantities of thiamin, riboflavin, calcium, and iron.

Disposition of the Carbohydrates. From the standpoint of type of growth, the vegetable crop legumes may be divided into two groups: (1) The determinate and (2) the indeterminate. The determinate types—the so-called dwarf varieties—extend their stems for a short distance only, usually until the first inflorescence appears; and the indeterminate types—the so-called pole varieties—extend their stems for a long distance, usually until growing conditions become unfavorable. Thus, with determinate types vegetative processes are dominant from the time of seedling emergence to the development of the first flower, and reproductive processes are dominant during the remainder of the life of the plant; and with indeterminate types vegetative processes are dominant from the time of seedling emergence to the development of the first blossoms, and neither vegetative nor reproductive processes are dominant during the remainder of the life of the plant. Soil management, fertilization, and cultivation practices are handled accordingly.

Snap Bean

Snap beans are of two types: the dwarf and the pole. Dwarf varieties produce short, erect, much-branched, indeterminate stems, and pole varieties develop long, twined, rarely branched, determinate stems. The leaves of both types consist of three leaflets. These leaflets are either broad, ovate, or long and narrow, and vary from light green to dark green according to the variety. The pods vary in shape (flat, oval, or round in cross section and straight or curved in longitudinal section) and color (yellow, light green, or dark green), according to the variety.

ECONOMIC IMPORTANCE AND PRODUCING CENTERS

Important producing districts for long distance shipment are located in central Florida, March to June (spring crop) and August to November (fall crop), near Charleston, South Carolina, March to June (spring crop) and September to November (fall crop), near Norfolk, Virginia (April to June), central Mississippi (May to June), and southern Louisiana (April

to June). Important canning areas exist in New York, Maryland, and California.

GROWING THE CROP

Of the two types the dwarf is the most important commercially. In the United States two crops are grown annually: the spring and the fall. Spring crops are grown in practically all regions of the United States and both spring and fall crops are grown in southern regions. In general, spring crops are planted immediately after the last killing frost in the spring, and fall crops are planted 50 to 60 days before the average date of the first killing frost in the fall. Seed are usually planted from 2 to 4 inches apart in rows 3, 3½, or 4 feet apart. The nutrients are applied in the furrow or on the side of the seed at rates varying from 400 to 1000 pounds per acre. To avoid the spreading of anthracnose and bacterial blight, cultivation, when necessary, is done when the foliage is dry.

MARKETING

Snap beans are harvested by hand. From two to five pickings are sufficient to harvest the dwarf varieties, while several more pickings are necessary for the pole varieties. In any case the pods are picked when they have reached their full size, but when the seeds are only about one-fourth mature. Shipping containers are bushel hampers, bushel crates, and ½-bushel baskets. For long distance shipment during hot weather, snap beans are always shipped under refrigeration. Figure 135 shows a harvest scene of snap beans in south Florida.

FIG. 135. A snap bean harvesting scene in south Florida. (Courtesy, R. V. Allison, Florida Agricultural Experiment Station.)

Lima Bean

As with snap beans, there are dwarf and pole types. However, unlike snap beans, there are two groups within each type: (1) The small-seeded and (2) the large-seeded. Plants of the small-seeded type have erect stems, glabrous, non-hairy leaves and small, numerous pods, while plants of the large-seeded types have large, thick leaves, and large, relatively few pods.

ECONOMIC IMPORTANCE AND DISTRIBUTION

Lima beans are grown in home gardens, in market gardens for local markets, in certain trucking regions in the Southeast for long distance shipment, in certain areas for canning, and on the coast of California for dehydration. In this region both the small-seeded and the large-seeded types are raised. About 400,000 hundred-pound bags of the small-seeded type and 800,000 hundred-pound bags of the large-seeded type are produced annually.

CULTURE

The cultural requirements for lima beans are similar to those for snap beans. For green-shelled bean production the bush types are planted in hills or in drills, and the pole types are usually planted in hills and are supported by stakes, poles, or wire trellis. The fertilizer is applied below or on the side of the seed, and the pods are harvested when they begin to turn yellow. For dry-shell bean production both types are planted in drills, and the pole varieties are allowed to spread on the land without support. In California the crop is grown during the dry season, and the dry soil does not injure the pods.

Edible Soybean

Soybeans are grown primarily for feed, as green-manuring crops, for oil, and for the manufacture of plastics. Within recent years varieties suitable for human consumption have become available. The plant characteristics of soybeans are similar to those of other beans. The root system is extensive and supports the growth of *Rhizobium*. The stems are erect, become woody with age, and the three leaflets are hairy and broad. The pods are small and contain from two to three seeds. Individual flowers are relatively small and white or purple. According to certain authorities, soybeans have the same climatic, soil, and cultural requirements as snap beans. Although

soybeans are grown extensively in China for human consumption, at present the crop is not widely grown for this purpose in the United States. Recent investigations have shown marked varietal differences in yield, flavor, and palatability of the seed.

Cowpea

Cowpeas are beans. They possess the trifoliate leaves characteristic of beans. Cowpeas are grown for many purposes: for hay, ensilage, pasturage, soil improvement, and for human consumption. Cowpeas are primarily warm-season crops. The plants are particularly adapted to the hot summers of the South. In home gardens the seed is planted from 2 to 4 inches apart in rows 3, 3½, or 4 feet apart. Suitable soils are well-drained, moderately to slightly acid, sandy loams and loams. Soils containing large quantities of available nitrogen are likely to induce the production of excessive vine growth and low yields. For human consumption the seeds are used either in the fresh or dry state.

Garden Pea*

Garden peas differ from beans in that the stems are hollow, the leaves are pinnately compound with one, two, or three pairs of leaflets, and a branched terminal tendril and large stipules; the flowers are borne singly or in pairs on long stalks; the pods are non-constricted and the seed is round, which in turn is either smooth, or wrinkled when dry.

ECONOMIC IMPORTANCE AND PRODUCING CENTERS

Garden peas are grown in home gardens, in market gardens, in winter garden areas for long distance shipment and in fields for canning and drying. Principal winter garden areas are located in California, Arizona, central and southern Mississippi, the coastal plain section of South Carolina and North Carolina, the eastern shore of Virginia, and Long Island, New York. Large quantities are raised for the cannery. Principal producing states are Wisconsin—with nearly one third of the total acreage, followed by New York, Washington, Montana, Oregon, Maryland, Illinois, and Michigan in the order named. For long distance shipment and for canning, the dwarf and semi-dwarf varieties are used. In home gardens the three types: dwarf, semi-dwarf, and tall varieties are grown.

*In southern United States garden peas are usually referred to as English peas, and edible varieties of cowpeas are called peas.

GROWING THE CROP

The climatic factor which gives the grower the greatest concern and which generally limits the production of peas in any particular part of the country is temperature. This crop is a native of, and particularly adapted to, the temperate regions of the old world. The growing seasons of England and northeastern Europe are particularly favorable and almost ideal for the growth and development of the plants. In the United States there are very few districts which have a growing season similar to that of these countries. Perhaps the growing season of the Puget Sound district of western Washington most closely approaches the climate of these countries. In this district large quantities of peas are raised for seed. Other regions which are less favorable but produce profitable crops are the New England States and the northern portions of the states bordering Canada. For the remainder of the country periods of favorable temperature are short and uncertain. In the corn belt and in the southern regions, early varieties of peas can be grown in the cool weather of spring but the late or tall varieties are destroyed by the heat of summer. The cool weather in the fall is again favorable for growing peas but this period of favorable weather is not sufficiently long for the maturation of the crop before frosts occur. Furthermore, the rainfall in the fall is usually insufficient for the rapid growth of the crop.

In home and commercial gardens the seed is planted about 1 inch deep in rows 2, 3, or 4 feet apart. In most of the winter garden areas single rows or double rows are used. If single rows are used, the distance between the rows varies from 2 to 3 feet. Where double rows are used, beds are made 4 feet apart and the rows of each bed are from 8 to 12 inches apart. Peas for canning are sown with grain drills, and the plants are hauled in bulk to the "viner" or shelling machine (see Figure 136).

MARKETING

Peas for home use and for the fresh market are picked by hand. The pods are picked when the peas are fully developed and when the percentage of sugars in the seeds is the highest. Immediately after the peas are picked the sugars in the seed begin to change to starch. The rapidity of this change is a function of temperature. In other words, the higher the temperature for any given period, the greater is the transformation. In addition, high temperatures induce a greater rate of respiration than low temperatures. To retain quality and sweetness peas are, therefore, har-

FIG. 136. The shelling of garden peas for the cannery in Indiana. Note that small crates are used to hold the shelled peas, and the vines are stacked for use as feed.

vested during the cool portion of the day, handled quickly in grading and packing, and in hot weather are shipped under refrigeration.

Questions

1. Botanically speaking, what is the fruit of the bean and garden pea?
2. In general, beans and peas require lesser applications of nitrogen than most other vegetable crops. Explain.
3. State the two types of snap beans.
4. Two crops of dwarf snap beans are raised annually in the South; only one crop is raised in the North. Explain.
5. Beans should be planted shallowly and in loose friable soil. Explain.
6. Usually beans are extremely vegetative and non-fruitful when grown in highly fertile soil. Explain.
7. In general, the light green-leaved varieties produce lesser yields than the dark green sorts. Explain.
8. Pole varieties of snap beans are grown more extensively in the southern regions than in the northern regions. Explain.
9. In general, the commercial fertilizer bill for growing snap beans is less than for many other vegetable crops. Explain.
10. What type of beans are grown in your community? Are they grown for long distance market, local market, or the cannery? Give reasons.
11. Name the two types of lima beans.

12. During hot dry weather the Henderson Bush lima develops a deeper root system and produces higher yields than the Fordhook. What is the relation of a deep root system to the yielding ability of the crop under conditions of high transpiration?
13. Gardeners use brush for tall peas and stakes or poles for pole beans. Explain.
14. Peas for early market are raised in the extreme South. Peas for canning are raised in Wisconsin and the eastern shore of Maryland. Explain fully.
15. In general, the earlier the planting of garden peas in southern United States with due consideration to frost, the greater is the yield. Explain fully.
16. Peas produce higher yields in cool weather than in warm weather. Explain.
17. How would you determine whether pea seed should be inoculated?
18. Your mother wishes information on the harvesting of peas so they will retain their sweetness. Outline two methods.
19. Ice is placed in the center of packages of peas shipped long distances. Explain.

MISCELLANEOUS CROPS

Cultivated Mushrooms

PLANT CHARACTERISTICS

Cultivated mushrooms are special varieties of the common meadow mushroom, *Agaricus Campestris.* Cultivated mushrooms are fungi. Like the higher plants, the plant body of mushrooms may be divided into two distinct parts: (1) The vegetative portion analogous to the roots, stems, and leaves of green plants and (2) the reproductive part analogous to the flowers, fruit, and seed. The vegetative part consists of fine white threads each about .001 to .002 of an inch in thickness collectively called mycelia. The reproductive part consists of the edible portion and has three distinct parts: (1) The convex cap or pileus, (2) the stalk or stipe, and (3) the annulus. The cap consists largely of radiating plates of spore bearing tissue called gills. The stalk supports the cap and the annulus protects the gills when the fruit is small. As the cap grows the annulus is stretched and finally ruptures giving the appearance of a collar-like structure around the stipe. The function of the mycelia is to absorb water, nutrients, and organic matter from the compost in which it grows. The function of the fruiting body is to produce spores which are analogous to the seed of higher plants.

CULTURE

Most cultivated mushrooms of the United States are grown in specially constructed houses made of wood, brick, concrete, or hollow tile. Standard houses are 20 feet wide and from 50 to 75 feet long. They have two tiers of beds and a service alley between each tier. Individual beds are usually 6 to 8 inches deep, 5 to 6 feet wide and run the entire length of the house with the exception of the alleyways at the end. The tiers of beds are supported by 2 x 4-inch uprights at intervals of 4 feet.

THE COMPOST

The mushroom fungus is a saprophyte; that is, it lives on dead organic matter. Growers have found that not all types of organic matter are suitable. The most desirable type is horse manure from grain fed animals mixed with wheat straw. This material undergoes a preliminary period of decomposition before it is placed in the beds and a final period before the crop is started. The initial period of decomposition is from 25 to 40 days depending on the condition of the manure and the temperature. When the manure has undergone its first period of heat production, it is placed in the beds at the rate of 1½ to 2 pounds per square foot of bedding space. At this point a second period of heat production begins. To facilitate a rapid rise of temperature in the houses, doors and ventilators are closed and in a few days maximum air temperatures of 120° to 130° F. take place, and manure temperatures of 130° to 140° F. are obtained. The high temperatures of the manure kill many competitive fungi and some of the insect pests. The remainder of the pests are driven to the surface of the manure and are killed by fumigating with sulfur.

SPAWNING

When the temperature of the compost has declined to 70° or 75° F., the crop is ready to be started. Cultivated mushrooms are started by means of spawn. Spawn consists of living mycelia growing in specially prepared organic matter. The making of spawn is a highly specialized business. In fact, it is just as highly specialized as the growing of seed of vegetable and flower crops. Principal operations consist of: (1) Collecting mushroom spores under aseptic conditions, (2) germinating the spores and growing the mycelia in potato-dextrose or beer-wort agar to make certain that the culture is free from contaminating moles and bacteria, and (3) transferring pure cultures of mycelia to sterile compost in quart milk bottles.

The material for the bottles is horse manure short in straw which has decomposed longer than that used in the beds. The decomposed material is packed firmly into the bottle and a hole is bored through the center for ventilation. The bottle is then plugged with cotton and sterilized with steam at a temperature of 70° to 80° F. The mycelia will ramify through the compost in 3 weeks after inoculation. Since the growing of mushroom spawn is highly specialized, most growers buy their spawn.

Planting operations consist of: (1) Breaking the bottle to remove the spawn, (2) breaking the spawn into pieces about one-half the size of a hen's egg, and (3) planting each piece of spawn about 1½ inches deep and from 10 to 12 inches apart in the beds. Immediately after planting, the temperature of the compost is maintained at 70° F. for about a week or 10 days to facilitate the rapid growth of the mycelia. Afterwards the temperature is gradually lowered to 55° F.

From 1 to 2 weeks after spawning the beds are cased. Casing consists of spreading a 1-inch layer of clay loam high in organic matter and lime over the beds. The function of casing is to facilitate the development of the fruiting bodies, the edible portion of the plant. Six to 8 weeks usually elapse between casing and the first picking.

MANAGEMENT

The management of mushroom houses is as exacting as that of greenhouses. The principal factors of successful management are the maintenance of proper temperatures, relative humidity, and a uniform moisture supply in the beds. As with higher plants, mushrooms have an optimum temperature range for growth. This range is from 65° to 70° F. during the development of the mycelia and from 45° to 55° F. during the development of the fruiting bodies. Experience shows that houses maintained within 45° to 55° F. produce excellent crops of large, firm, high quality mushrooms for a period of 5 to 6 months and that houses held between 55° and 65° F. produce only for a period of 3 to 4 months. Temperatures above 65° F. cause a serious reduction in yields.

The relative humidity is maintained usually between 70 and 80 per cent. If the humidity drops below 70 per cent the casing soil dries out rather rapidly and the mushrooms become tough and leathery. However, if the relative humidity is maintained above 80 per cent the "spot" disease is likely to become serious.

A uniformly moist compost and casing soil are necessary at all times for high production. Uniformity is accomplished by frequent sprinkling of the

beds and by a slow but gradual loss of water from the beds. Excessive water favors the development of green mold and causes the small mushrooms to turn brown and die. If, however, the compost is dry, few mushrooms will develop and these will form beneath the soil layer.

HARVESTING

Mushrooms are gathered about 12 hours before the annulus or veil would normally rupture. The stalk is pulled from the mycelia and then removed from the cap. The caps are then graded and packed in 1-pound cartons. Mushrooms are usually sold by weight.

PRODUCING CENTERS

Most of the cultivated mushrooms grown in the United States are produced in eastern Pennsylvania within an area bounded by a radius of 25 miles with Kennett Square as the center. Within this area lies West Chester, sometimes called the mushroom capital of America. Between 30 and 40 million pounds are produced annually.

HERBS

Herbs are grown for their flavor and fragrance, particularly in the preparation and serving of cooked foods for the table. They comprise a miscellaneous group. Some are annuals; some are biennials; and others are perennials. Some are grown for their leaves; others for their flower parts; and others for their seed. In general, a few plants of any one kind will supply the needs of an individual family. A list of some of the common herbs follows:

Herbs grown for their leaves:

Perennials—balm, catnip, lavender, peppermint, spearmint, rosemary, sage, and thyme.

Annuals—summer savory and sweet majoram.

Herbs grown for their flower heads:

Biennials—dill.

Herbs grown for their seeds:

Biennials—caraway.

Annuals—anise and coriander.

Questions

1. In what respects are mushrooms similar to higher plants? in what respects are they different?

2. From your knowledge of the effect of temperatures above the optimum range for growth, how do high temperatures lower the yield of mushrooms?
3. The commercial mushroom industry is located about 35 miles west of Philadelphia. Give two reasons.
4. In the home garden would you place the annual and perennial herbs in the same location? Give reasons for your answer.

22

Commercial Floriculture

Assignment 30

"Habits and customs differ, but all people have the love of flowers in common."
—Chinese proverb.

Most people like flowers. In general, flowers are used to express human sentiments and to beautify the environment. Since in this age of specialization many people have neither the time nor the facilities nor the "know-how" that is required for raising flowers, they buy flowers. At present, most flowers are sold for use at weddings, funerals, social functions, and as gifts.

The initiation and development of commercial production coincided with the growth of cities and the social activities of the people. According to Laurie and Kiplinger, the growing of flowers for sale in the United States began in the vicinity of Philadelphia during the early part of the 19th* century. At first only outdoor gardens and fields were used. Later, as the demand for "out-of-season" flowers increased, greenhouses were erected. Still later, in common with the growth of the fruit and vegetable crop industries, the services of the middle man became necessary. Thus, at present, there are wholesale florists who are primarily production specialists or commission merchants; and retail florists who are primarily salesmen; and retail growers who primarily grow and sell their own products.

Principal factors concerned in the growth of commercial floriculture

*According to the first official census, taken in 1790, the three largest cities ranked as follows: Philadelphia with 42,444, Boston with 33,131, and New York with 18,038.

are: (1) The formation of the Society of American Florists, (2) the development of the Florists' Telegraph Delivery Association (FTD), and (3) the work of the Land Grant College System and the United States Department of Agriculture. The Society of American Florists initiated the unique and effective advertising slogan "Say It With Flowers." This slogan appeals to the public; it is catchy; and it is all inclusive. The Florists' Telegraph Delivery Association provides facilities for the buying of flowers in any part of the United States and in many other countries of the world. For example, suppose a student wants to buy a corsage for his friend, and he wants to have the corsage presented to the friend as she starts from home to the campus for a visit. He would go to, or phone, the local florist; the local florist would transmit the order, usually by wire, to a florist in the friend's home town who would make up and deliver the corsage to her as she starts on her journey. Thus, the service rendered by FTD insures quick and prompt delivery of fresh, high quality products. As such, it has been of great benefit both to the producer and to the consumer. The work of the Land Grant College System and the United States Department of Agriculture consists of the training of students in floriculture, the solution of problems of the many ornamental industries and the dissemination of research results to producers and consumers. The training of students in and the solution of problems by the scientific method have assisted greatly in placing the many industries on a comparatively firm foundation.

The growing of ornamental plants for sale is divided into the following distinct industries: (1) The production of cut flowers and (2) the production of potted plants. Since these industries have special requirements, facilities, and technical knowledge, they are highly specialized.

PRODUCTION OF CUT FLOWERS

Cut flowers are produced in greenhouses, cloth houses, and outdoors. Greenhouses are used for both warm and cool-season crops during the entire year. Principal crops are: rose, carnation, chrysanthemum, sweet pea, snapdragon, orchid, and gardenia. In general, the principal environmental factors—water, temperature, light, and nutrients—are either under entire or partial control. The water is supplied by many specialized irrigation systems and devices; the temperature is either thermostatically or manually controlled; the light intensity is reduced by the use of shading material or increased by the removal of the shading material; the photoperiod is reduced by the use of black cloth or increased by the use of electric lights; and the nutrients are supplied in solution for the growing

of crops in media other than soil and in the form of organic matter and commercial fertilizers for the growing of crops in sand or soil.

Cut flowers are grown in either ground beds or in raised 4- or 5-foot wide benches. Two types of benches are used: (1) The level and (2) the V-shaped. These in turn may be water tight or non-water tight. In general, the water tight bench requires the V-shaped bottom and a layer of tile or gravel at the bottom of the V. With this type of bench the crops can be irrigated by maintaining a constant level of water in the bottom of the bench or by running water through the tile line or through overhead pipes. In general, the non-water tight bench is either V-shaped or flat and requires a layer of sand or gravel at the bottom. With this type of bench the crops are watered by overhead systems of irrigation. Various systems are used: the hand, Skinner, Revere, and Ohio State are examples. Various types of construction materials are used in the making of benches: wood (cyprus or redwood), concrete, concrete slabs, Transite (a mixture of asbestos and concrete compressed into thin sheets), aluminum alloy, steel, and tile. Of these, the wooden bench is the most common, the least durable, and in the long run the most expensive.

Cloth houses are used whenever outdoor temperatures are favorable for the growth of crops. Principal crops grown are: the pompon varieties of chrysanthemum, aster, snapdragon, and rose. Under conditions of high light intensity and high transpiration, crops grown under cloth produce longer stems, larger leaves, and larger and brighter flowers than comparable crops grown outdoors. How is the more satisfactory growth secured? The fundamental process concerned is transpiration and the principal environmental factors concerned are: (1) Temperature, (2) light intensity, (3) relative humidity, and (4) wind velocity. Experiments at the Ohio Experiment Station have shown that the cloth slightly lowers maximum daily temperatures and slightly increases relative humidity. However, it markedly lowers light intensity. Study the data in Table 26. Note that the greater the intensity of light, the greater is the reduction. The decrease in light intensity in cloth houses undoubtedly decreases the rate of transpiration. This in turn permits water absorption to keep up with transpiration. This in turn maintains turgor of the guard cells and keeps the stomata open for a longer period than the higher light intensity outdoors.

In general, cloth houses are placed on the leeward side of the service building to obtain protection from cold winds and a sufficient distance from trees to avoid shading by the branches and the invasion of roots into the soil of the house. Construction is relatively simple. White cloth with 22

Table 26

Effect of Cloth on Reduction of Light Intensity*

Treatment	In a Laboratory		In Sunlight Outdoors	
	Foot Candles	Reduction Per Cent	Foot Candles	Reduction Per Cent
No cloth	45	..	11,500	..
Cloth	37	17	7,474	35

*After Laurie and Kiplinger, "Commercial Flower Forcing," Philadelphia, The Blakiston Company.

threads per linear inch, 33 feet 4 inches wide, and of any desirable length is used. This cloth is supported by either wood (locust, cedar, chestnut, or redwood) or iron posts placed 4 feet deep, 6 feet 8 inches high, and 16 feet 6 inches apart. Beds 54 inches wide and 100 feet long are recommended. Note the greenhouse roses growing in the cloth house in Figure 137.

Outdoor culture requires the utilization of temperatures which are favorable for the growth of the crop in question. In other words, the crops are grown at temperatures within their optimum temperature range. The principal crops are: chrysanthemum, aster, and gladiolus. Chrysanthemums and asters are grown principally in the vicinity of Los Angeles, California, and gladiolus in many parts of the country. Producing districts exist in central Florida, southern Alabama, the coastal plain section of North Carolina and South Carolina, northern Indiana, northern Ohio, and southern Michigan. In this way a succession of crops is produced with Florida, the earliest producing district, supplying the markets from October to May; and Michigan, the latest producing district, supplying the markets from August to September. Thus, the flower spikes are made available in many markets throughout the entire year.

Keeping Quality of Cut Flowers. The fundamental processes concerned are: (1) Water absorption and transpiration and (2) respiration. With water absorption and transpiration the principal plant factors are: (1) The relative area of absorption and (2) the water-holding capacity of the tissues. The principal environmental factors are: (1) Temperature, (2) relative humidity, and (3) wind velocity. Since cut flowers can absorb water only through the stem, the area of absorption is exceedingly small compared to the area of transpiration. Thus, the utilization of environmental factors that will reduce the rate of transpiration will accordingly reduce water deficits and prolong the life of the flowers. With respiration

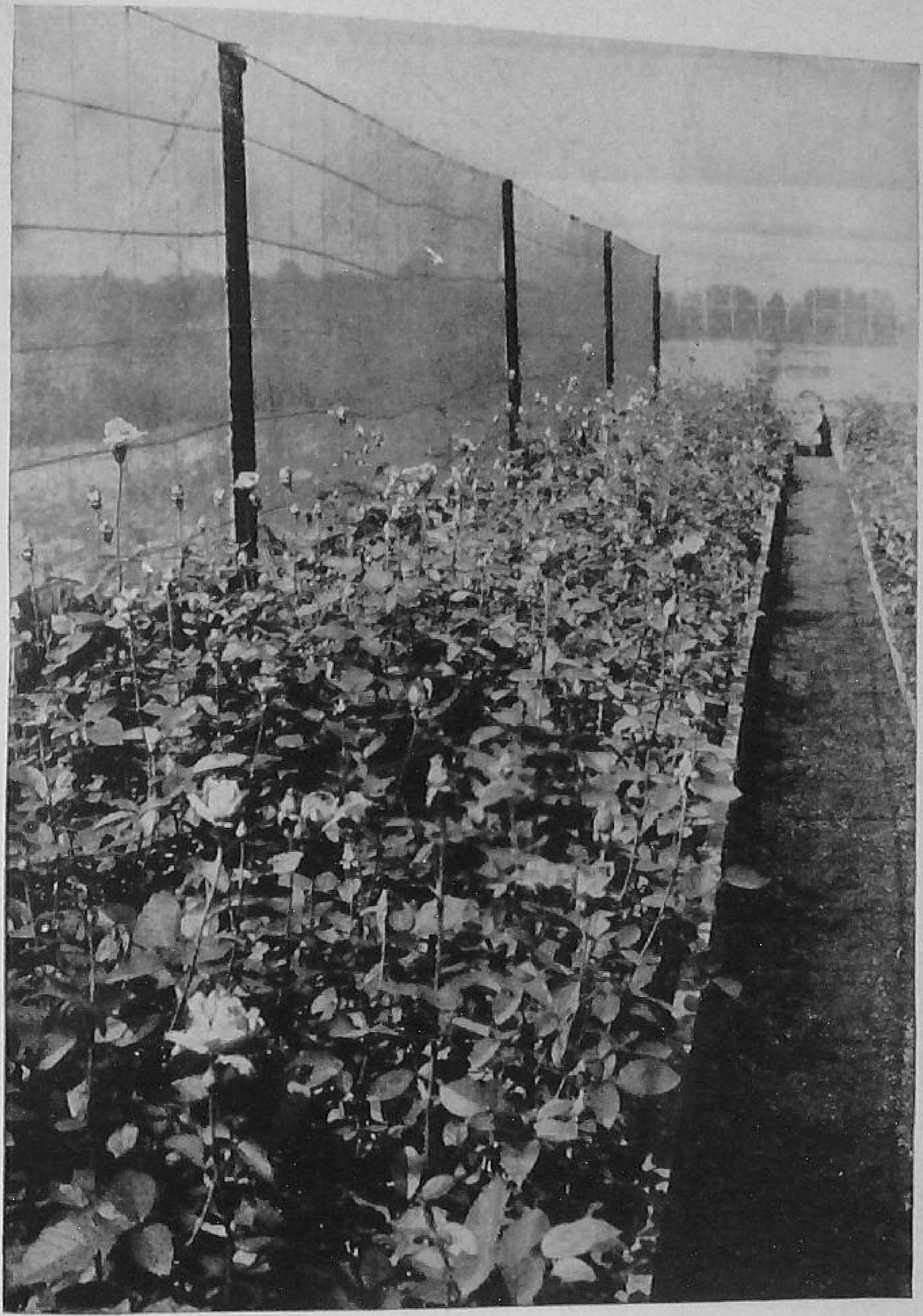


FIG. 137. Greenhouse roses growing in cloth house. (Courtesy, Laurie and Kiplinger: "Commercial Flower Forcing," Philadelphia, The Blakiston Company.)

the principal plant factor concerned is the amount of sugars available, and the principal environmental factors are: (1) Temperature and (2) use of certain chemicals. Since sugars are used in respiration, the greater the actual and potential sugar supply at the time of cutting and the lower the rate of respiration after cutting, the longer will be the life of the flowers. Thus, high sugar content in the tissues should be promoted and low temperatures utilized whenever feasible. In regard to the use of chemical compounds, certain substances have been found that substantially lower

the respiration rate and greatly retard the activity of bacteria and fungi that rot the stems. These substances are placed in the water in which the stems are emerged. Two preparations are: (1) A solution consisting of hydrazine sulfate, manganese sulfate, and sugar, and (2) a solution consisting of potassium, aluminum sulfate, sodium hypochlorite, ferric oxide, and sugar. Commercial preparations are Floralife and Bloomlife. Retail florists frequently place a tablet of these materials in each pack of flowers sold.

FIG. 138. A consumer unit package of roses. Note the droplets of water on the leaves and petals. (Courtesy, Alex Laurie, Ohio State University.)

Prepackaging of Cut Flowers. Prepackaging consists of packing an average size consumer unit in an appropriate package. The processes concerned are: (1) Respiration, (2) transpiration, and (3) rate of cell division. Naturally for long storage life and long keeping quality, the flowers should have a low rate of respiration, a low rate of transpiration, and a low rate of cell division. How does the package maintain a low rate of these processes? To maintain a low rate of these processes the package should fulfill the following requirements: it should have a small volume, and it should be non-water absorbent, gasproof, and sufficiently strong to withstand handling.* The relatively small volume combined with "misting" of the flowers and the non-water absorbent quality of the material maintains a high relative humidity. Thus, a low rate of transpiration is maintained. The relatively small volume combined with the gasproof quality of the cellophane wrap maintains a certain concentration of carbon dioxide—usually from 5 to 15 per cent. Thus, a low rate of respiration is maintained. The fact that the stems are not placed in water permits a slight water deficit within the tissues. Thus, a low rate of cell division is maintained. Figure 138 shows a consumer unit package

*The packages also have a cellophane window so that the consumer can see what he is buying.

Fig. 139. A self-service cabinet for the selling of prepackaged flowers. (Courtesy, Alex Laurie, Ohio State University.)

of roses, and Figure 139 shows a refrigerated self-service cabinet for selling consumer units.

PRODUCTION OF POTTED PLANTS

The growing of plants in pots and similar containers differs from the growing of plants in the greenhouse bed or bench, the garden, field, or orchard. The volume of soil in the container is exceedingly small; the root system of the plant is greatly restricted; the natural nutrient supply is limited; and the necessity for frequent watering is conducive to the leaching of nitrates and possibly other nutrients. Thus, soils for growing plants in containers are reinforced with heavy applications of highly decomposed organic matter and with heavy applications of commercial fertilizers. In fact, fertilization at the rate of 2 to 4 tons per acre is not uncommon. In general, three operations are required in the production of potted plants: (1) The growing of seedlings in porous, well-aerated, infertile soil in flats, benches, or beds, (2) the transferring of the seedlings to a small clay pot (1- or 2¼-inch) containing relatively infertile soil, and (3) the transferring of the plant to the final or "finishing" pot. The size and type of the final pot depends largely on the type of plant and the root system. Types

of pots are: (1) Standard (width of the top and height are the same), (2) pan (height equals one half of the width), (3) azalea (height equals three quarters of the width), and (4) rose (height equals one and one quarter of the width). *Shifting*, the transferring of seedlings to small pots or of plants from small pots to final pots, presents an excellent opportunity for the planter to practice both the science and art of growing plants. Millions of excellent plants are produced each year. Some common ornamental pot plants are shown in Figure 140.

In general, plants growing in pots and other containers may be divided into two groups: (1) Those grown primarily for their flowers and secondarily for their foliage and (2) those grown for their foliage only. Principal plants of the first group are: geranium, azalea, hydrangea, and *Saintpaulia*. Principal plants of the second group are: *Asparagus plumosus*, *Asparagus sprengerii*, Boston fern, poinsettia, *Sansevieria*, and rubber plant.

CARE OF PLANTS IN THE HOME

In general, the environment of the dwelling house is less favorable for the growth and development of plants than that of the greenhouse or conservatory. The light intensity is very low, unless the rooms are thermostatically controlled the temperature fluctuates widely, and the relative humidity is exceedingly low. The low light intensity makes for a low rate of photosynthesis, and the low relative humidity makes for a high rate of transpiration. Thus, plants which are adapted to the relative adverse conditions of the home should possess at least one, and preferably all, of the

FIG. 140. Some ornamental pot plants. (*Upper row, left to right*) Maidenhair fern, orchid, Jacobinia, poinsettia, and Boston fern. (*Lower row, left to right*) Pothos, begonia, kalanchoe, azalea, chrysanthemum, and *Saintpaulia*.

following physiologic characteristics: (1) They should make foods under poor light conditions, (2) they should make substances which bind water, and (3) they should have a low rate of transpiration. As might be expected, plants vary in these respects. Thus, they vary accordingly in their adaptation to conditions of the dwelling house. Some are well adapted, others are moderately well adapted, and others are only fairly well adapted. Examples are presented in Table 27.

Table 27

FLOWER AND FOLIAGE PLANTS BASED ON ADAPTATION TO CONDITIONS OF THE DWELLING HOUSE

Excellent	*Average*	*Fair*
	Flower and Foliage	
azalea, cyclamen, geranium, hydrangea, *Saintpaulia*	calceolaria, chrysanthemum, gardenia, petunia, poinsettia	cineraria primula *Solanum pseudo capsicum*
	Foliage	
aspidistra, cissus, philodendron, Boston fern, succulents	trandescantia, vinca major, pothos, dracena	croton Maidenhair fern

GROWING AND FORCING OF STORAGE STRUCTURES
(Bulbs and Corms)

Certain ornamental plants produce storage structures—bulbs and corms. These fleshy structures are developed for the storage of relatively large quantities of reserve carbohydrates—usually hemicellulose or starch. These reserve substances are changed later to sugars and other similar compounds for the development of roots, stems, leaves, and flowers. Naturally, with other factors favorable, the greater the amount of carbohydrates which are stored, the greater will be the production of roots, foliage, and flowers. Major crops are gladiolus and lily; minor crops are iris, narcissus, hyacinth, and tulip. In the commercial production of these crops two more or less distinct industries have developed: (1) The production of the storage structures with the simultaneous development of foliage and flowers and (2) the forcing of the storage structures in greenhouses.

Production of Storage Structures. Although the details of cultivation vary with the crop, the main object for all crops is the rapid develop-

ment of large storage structures tightly packed with reserve food. Thus, as in the development of onions, potatoes, root crops, and sweetpotatoes, the sequence of events is as follows: the development of absorbing roots and a large photosynthetic surface during the first part of the growing season, and the development of the storage structure during the latter part. Consequently, carbohydrate utilization is dominant during the first part of the growing season, and accumulation is dominant during the latter part. For example: in the production of gladiolus corms in southwestern Michigan cormels (small corms) are planted 4 to 6 inches deep and 3 to 6 inches apart in rows 2, 2½, or 3 feet apart in well-drained, moderately acid, sandy loams. At first, the cormel develops the absorbing root system and then it develops one, two, three, or four stems. When these stems are 6 to 8 inches high, their basal portion starts to enlarge, and when the stems are 18 to 24 inches high, the young corms are fully grown. At the same time, cormels arise from adventitious buds between the old and new corms. In this way a comparatively large number of corms are produced. The new crop of corms are harvested when the leaves turn yellow or just before the first frost.

In general, commercial districts may be divided into two groups: (1) The southern district in which flower production is the main consideration and (2) the northern district in which corm production is the chief consideration. Outstanding southern districts are located in central Florida and the Mobile Bay area of Alabama. An important northern district is the Holland-Zeeland area of southwestern Michigan.

Forcing of Storage Structures in Greenhouses. In greenhouse forcing the main object is to produce attractive foliage and brilliant flowers for sale at the right time. To attain this objective certain practices are common to all flowering bulbs and corms and certain practices are specific. Common practices are: (1) The use of large, well-developed disease-free bulbs or corms, (2) the development of an extensive root system during the first part of the forcing period, and (3) the development of stems, leaves, and flowers during the latter part. Specific practices are: a storage period of 4 weeks at 31° to 35° F. for the Easter lily and a conditioning period of 2 weeks at 80° to 85° F. in moist media for the gladiolus. The specific treatment for the Easter lily is necessary to hydrolize the hemicellulose to soluble forms and to initiate the development of flower primordia, while the conditioning period for the gladiolus is necessary to develop a large number of cells within the growing points before root production begins. The forcing of bulbs or corms is entirely a carbohydrate utilization process.

Of the various kinds of flowering plants that are forced from storage structures, the Easter lily is the most important commercially because of the demand as a potted plant at Easter. Since the Easter lily must look its best on 1 or 2 days only, and preferably on Easter Sunday, a very precise synchronization of treatments and practices has been worked out from the time the bulbs are harvested to the time Easter occurs.

The storage structures of iris, hydrangea, narcissus, and tulips are also forced. The proper size of the bulbs or corms, the preconditioning treatment before forcing, the type of forcing container and media, and the level of the forcing temperature for Thanksgiving, Christmas, or post-Christmas trade are rather specific and exacting. These specific requirements have been developed by growers and certain experiment stations.

Questions

1. State the three factors which have been responsible for the development of commercial floriculture.
2. What is the FTD?
3. You want to send a gift of flowers to a friend living in another region. How would you go about it?
4. Under what conditions do you consider flowers a luxury? Under what conditions do you consider them a necessity? Explain.
5. Show how the law of mass action applies to the prepackaging of cut flowers.
6. In your opinion which is more important in prolonging the life of cut flowers in a room, a low transpiration rate? or a low respiration rate? Explain.
7. How does the production of cut flowers in greenhouses differ from the production of cut flowers in cloth houses?
8. Under conditions of high light intensity and high transpiration, pompon chrysanthemums and asters grown under cloth produce longer stems, larger leaves, and larger flowers than comparable plants grown outdoors. Explain.
9. In your opinion in what region of the country could cloth houses be used for the longer period? Explain.
10. Locating cloth houses near large trees should be avoided. Give two reasons.
11. The exclusion of bees by cloth houses prolongs the life of cut flowers. Explain.
12. What are the differences and similarities in growing plants in a garden and growing plants in pots, hanging baskets, or similar containers?
13. Some people have difficulty in growing plants in containers successfully; others have very little difficulty. How do you account for these differences?

14. Outline the characteristics a plant should possess to be adapted to the relatively adverse conditions of the dwelling house.
15. What is the difference in morphology in bulbs and corms?
16. The forcing of bulbs and corms is entirely a carbohydrate utilization process. Explain.
17. In the greenhouse production of flowering bulbs and corms, extensive root development is necessary before foliage and flower production. Explain.
18. During the rooting period of bulbs and corms, soils should be low in nitrates. Explain.
19. Lily bulbs 5 to 7 inches in diameter produce from three to five flowers per plant, and bulbs 8 to 10 inches in diameter produce from five to seven flowers per plant. Explain.
20. Under optimum conditions in the greenhouse, large gladiolus corms flower 2 weeks earlier than relatively small corms. Explain.
21. When field produced gladiolus spikes are cut, at least four leaves should be left on the remaining stalk. Explain.
22. Given two lots of lily bulbs of equal size for planting in the field. Lot A was planted late and harvested early and produced from one to two flowers per plant; lot B was planted early and harvested late and produced from five to seven flowers per plant. Explain.

23

Nurserv Plants

Assignment 31

The nurserymen's forte: *To make the world more beautiful and fruitful.*

In general, nursery plants are young trees, shrubs, or herbaceous plants which are grown on specialized farms and which are transplanted to another location. These plants may be divided into two more or less distinct groups: (1) Young trees of the tree fruits and plants of the small fruits and (2) young ornamental plants. The former are grown to establish the many kinds of orchards and small fruit plantations, and the latter are grown to landscape or beautify homes, public and private buildings, schools, highways, parks, and industrial areas.

Distribution. The geographic location of outstanding nursery districts is presented in Figure 141. Note the large number of nurseries in the Northeast and Great Lakes region, in the Southeast and Gulf Coast region, and in the Pacific Coast region and the small number of nurseries in the Great Plains and Intermountain regions. Can you think of any reason for this?

NATURE OF THE NURSERY BUSINESS

Types of Nurseries. In general, the nursery business may be divided into three more or less distinct enterprises: (1) The production of seedlings from seed or by the various methods of vegetative propagation, (2) the growing of young plants to marketable size, and (3) the selling of market-

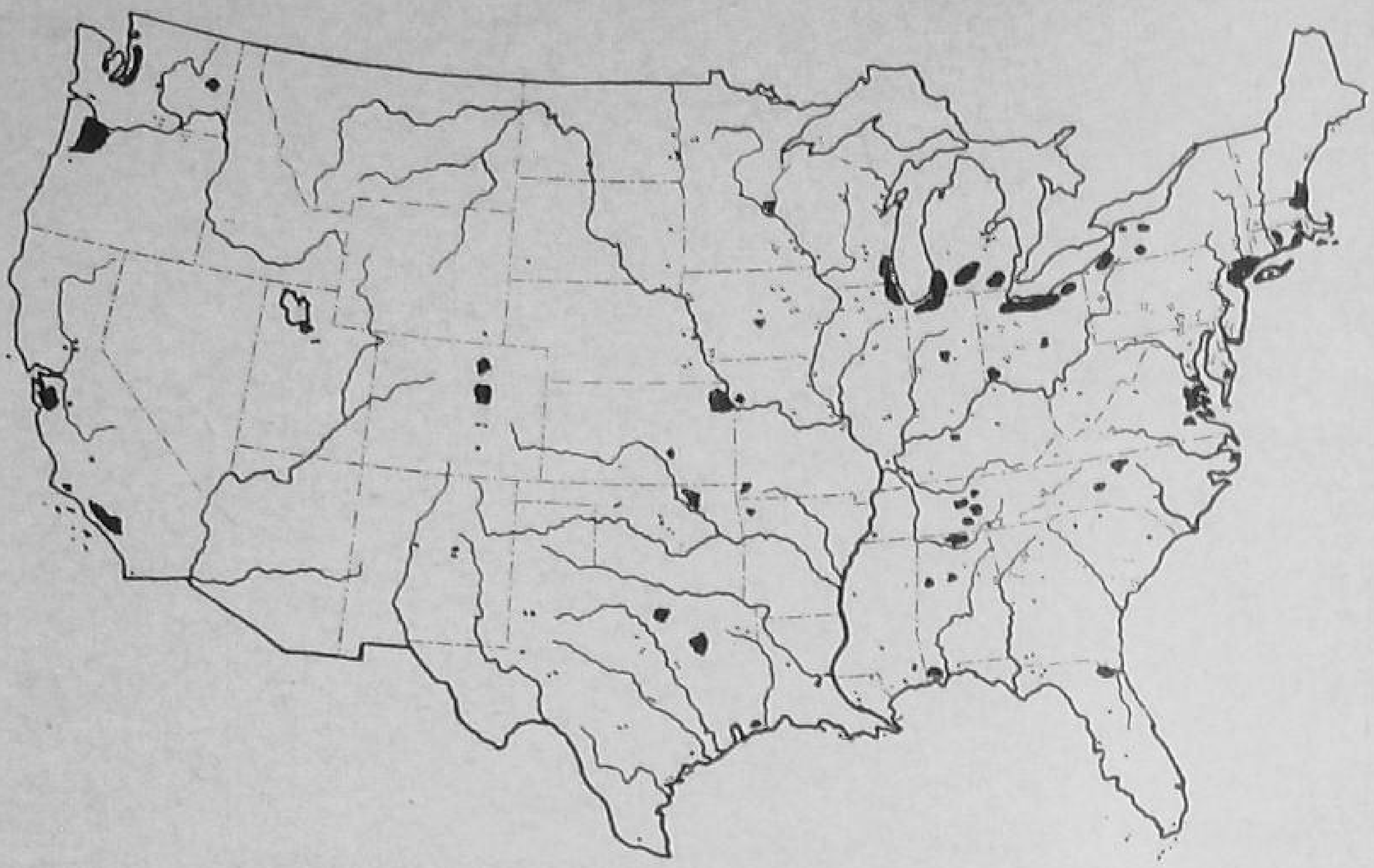


FIG. 141. Geographical location of nursery plant districts.

able stock. Some nurseries grow seedling plants only; others sell nursery stock only; and others engage in any two or in all three enterprises.

The Propagation Unit. The object of the propagation unit is to produce young plants. The layout may be divided as follows: (1) The actual propagating structures or beds and (2) the service structures. Principal propagating structures are: greenhouses, hotbeds, cold frames, specially constructed propagating frames, and outdoor propagating beds. In general, the greenhouses are equipped with benches which contain the appropriate bedding media and are maintained at high relative humidity and low light intensity; and hotbeds are heated by hot water, steam, or electricity. For the successful propagation of certain plants special propagating frames have been developed. An example is the Wardian case. The Wardian case is essentially a tightly constructed cold frame. The tight construction maintains a high relative humidity which is necessary for the successful union of the cambium in the grafting of coniferous evergreens and roses. Observe the non-wood lath house used for the starting of azaleas in Figure 142.

Principal service structures are the head house, storage house, heating plant, and alley house. The head house is essentially the service house for the greenhouses and hotbeds, and contains storage space for pots, flats, fertilizers, spray materials, tools, and work benches. The storage house contains rooms for the storage of seed and other propagating materials and the heating plant contains the boiler, fuel, and work benches. At some

Fig. 142. A lath house made of Flexboard supported by iron rods. (Courtesy, A. C. Oelschig and Sons, Savannah, Georgia.)

nurseries any two or all three of these structures are combined into one house. The alley house connects the greenhouses, hotbeds, and cold frames with the head house. Its main function is to provide a passage way for the transportation of plants, propagation media, soil, and fertilizers for the head house to the propagation structures and to and from the propagation structures themselves. Alley houses sufficiently wide to permit the use of a truck greatly facilitate the movement of these materials. In the growing of the seedling plants the two modes of plant propagation: (1) Propagation by seed and (2) propagation by vegetative means, are used. Important nursery practices in the use of seed are: (1) Collecting the fruits, (2) extracting and drying the seed, and (3) applying certain storage or pregermination treatments. *Collecting the fruits* consists of gathering mature fruit. Maturity varies with the kind of plant. In general, fleshy fruits become soft (apple, peach, plum); dry, green fruits become dark brown (oak); and winged fruits become light green or yellow (maple). Many types of equipment for harvesting fruit and seed are used: wire nippers, ladders, bags, cutting hooks, tarpaulin, and seed sheets are examples. *Extracting and drying the seed* consists of separating the seed from the fruit and drying the seed to a low water content. Numerous extracting methods and techniques have been developed. In general, these methods

vary according to the kind of fruit and are classified as follows: (1) Rubbing fleshy fruits on and seed through a 2- or 3-mesh screen, (2) running fruits through a macerator with or without water, and (3) heating dry fruits lightly and running the seed through a screen. *Storage or pre-germination treatments* consists of two types: (1) Scarification of the seed coat and (2) stimulation of the embryo. Scarification is necessary for seed with impervious coats to admit water and/or oxygen for germination. Three methods are used: (1) Emersing the seed in concentrated sulfuric acid from 20 minutes to 4 hours, according to the kind of seed, (2) revolving seed in a steel drum at about 20 r.p.m., and (3) soaking the seed in hot or cold water. Stimulation of the embryo is necessary to shorten its rest period. Numerous investigations have shown that the period of rest or period of after-ripening is shortened by placing the seed in moist media held at temperatures varying from 32° to 40° F. or by planting the seed in the fall. For example, seeds of the highbush blueberry will complete their period of rest in about 3 or 4 weeks if they are stratified and placed in cold storage. On the other hand, the period of rest requires from 3 to 5 months if the seeds are stored in a dry place. The method of vegetative propagation varies with the kind of plant. In general, cuttage is used for the propagation of herbaceous ornamentals and most woody plants, and graftage is used for the propagation of certain woody plants, the tree fruits, coniferous evergreens, roses, and so forth.

The Production Unit. The object of the production unit is to grow the nursery stock from the seedling stage to the marketable stage. The land is laid out in blocks and each block is given over to one kind of plant only. In this way the keeping of records is greatly facilitated. Principal practices are: (1) Lining-out, (2) top-pruning, (3) root-pruning, (4) plant removal, (5) storing, and (6) packing.

Lining-out. Lining-out consists of transplanting the nursery stock from the propagation unit to the production unit. An individual plant is called a "liner," and methods of lining-out vary greatly with the kind of plant. In general, the plants are lifted, sorted, root-pruned if necessary, placed in transplanting shelters, and placed in transplanting boards if hand transplanted and in the transplanting machine if machine transplanted. Many kinds of transplanting machines have been developed.

Top-pruning. Top-pruning consists of the removal of branches or parts of branches in order to develop the proper framework or form of the tree. The type of framework varies with the kind of plant. For example, with deciduous shade trees for street planting the branches on the lower part

of the trunk are removed, while with apple and peach trees a specific number of lower branches are allowed to remain.

ROOT-PRUNING. Root-pruning consists of the removal of portions or all of the younger portion of the roots. The object of this practice is to develop extensively branched root systems at the base of the tree. In this way recovery from transplanting is facilitated. This practice is particularly necessary for the transplanting of evergreens. Can you think of any reason for this? In general, root-pruning is done in the fall and many types of power-drawn cutting blades have been developed.

PLANT REMOVAL. Plant removal consists of removing the plant with part of its roots from the soil. Thus, water absorption stops or is greatly reduced. However, transpiration continues to take place. As a result, plant removal is done in the fall, winter, or early spring when transpiration is at a minimum. Two rather distinct methods of plant removal are used: (1) Lifting and moving without soil around the roots (bare root) for deciduous plants and small evergreens and (2) balling and burlapping for large evergreens and other plants which require considerable care in transplanting. Lifting may be done by hand with a sharp spade or by machine, and balling and burlapping is usually done by digging a trench at the required distance from the base and around the root system of the tree and enclosing the mass of soil and roots in burlap. In this way, the root system within the ball of soil supplies the leaves with the necessary water.

STORING. Storing consists of subjecting the plants to a set of environmental conditions which maintain life processes at a minimum. The fundamental processes concerned are respiration and transpiration and in general, the lower the respiration and transpiration rate, the longer is the storage life. Temperatures varying from 34° to 38° F., combined with relative humidity varying from 85 to 90 per cent and abundant ventilation, are usually used. The temperature from 34° to 38° F. not only permits a low rate of respiration but also helps to bring woody plants out of the rest period; the high humidity permits a low rate of transpiration without excessive development of molds and fungi; and the abundant ventilation supplies sufficient oxygen and carries away the carbon dioxide and heat of respiration. In general, there are two types of storages for nursery stock: (1) Inside and (2) outside or heeling in. Inside storage requires the use of specially constructed houses usually with three parts, (1) The work rooms, (2) the packing rooms, and (3) the storage rooms. For the most part, the storage rooms contain a series of deep shelves with vertical par-

titions. In this way stock of a given kind can be stored separately and maximum use of the storage house can be maintained. The use of storage houses permits grading, packing, and shipping during the winter, particularly in cold climates. Outdoor or heeling in storage requires the use of well-drained sandy loam, preferably adjacent to an all-weather road and the packing shed. Sandy loams with adequately drained subsoils are ideal since they do not become waterlogged in wet weather. Thus, nursery stock can be heeled in or removed at any time the soil is not frozen. Because of the mild winters, outdoor storage is used more extensively in the South than in the North.

Packing. Packing consists of preparing the nursery stock for shipment. Type of package varies greatly depending largely on the kind of plant, whether deciduous or evergreen, and on the size of the stock. In general, nursery stock is shipped according to the recommendations of the American Nurserymen's Association. Evergreens are usually shipped individually because of the necessity of balling and burlapping, and deciduous stock is usually shipped "bare-rooted" with the roots packed in moist sphagnum moss, peat, or shingle tow and with the top either covered with dried stalks or rushes and the entire plant wrapped in burlap or placed in a box lined with waterproof paper. Because parcel post shipments are frequently mailed in airtight containers, shipments by express are usually preferred. Note the block of young peach trees in Figure 143 and the blocks of azaleas in Figure 144.

The Sales Unit. The object of the sales unit is to market nursery products effectively. In other words, the sales area is located, designed, and maintained to attract the largest number of potential customers. Thus, the

Fig. 143. A block of young peach trees. (Courtesy, Bountiful Ridge Nurseries, Princess Anne, Maryland.)

FIG. 144. An attractive well laid out field of azaleas. (Courtesy, Howell Nursery, Semmes, Alabama.)

sales unit is usually located on a well-traveled highway and may be operated as a separate self-contained unit or in conjunction with the propagation or production units. In general, a well-developed sales unit contains: (1) A display or show area, (2) a sales area, (3) a parking area and drives, and (4) the service section. These areas are usually arranged in proper proportion and balance and provide an attractive landscape atmosphere.

DISPLAY OR SHOW AREA. The display or show area contains plants that are on display. The plants in this area are usually not for sale and they are arranged to show the effective use of landscape materials. Thus, the display area may show foundation plantings for small homes, pleasing combinations of trees and shrubs, or various kinds of gardens, such as the informal, formal, rose, azalea, camellia, or bulb.

SALES AREA. The sales area presents the materials that are for sale. In general, this area contains the business office with at least three essential features, the reception and display room for materials that should be kept dry, such as seeds, bulbs, spray materials, catalogues, and books, the landscape or drafting room and wrapping, storing, and toilet facilities; and greenhouses for house plants, lath houses, vents or terraces for potted plants and pergolas for vines.

PARKING AREA AND DRIVES. The parking area and drives provide ample space for customers' cars and free access to all parts of the sales and display areas. In this way the loading of bought materials is facilitated.

SERVICE AREA. The service area contains facilities for the maintenance of display and sales areas. Principal features are work rooms for potting

plants and other garden operations; storage bins for soil, peat, moss, manure, or sand; storage space for pots, labels, commercial fertilizers, pest control materials, and wrapping materials; garage and parking space for employees and heeling in space. Note the arrangement of various areas in Figure 145.

Opportunities in Nursery Stock Production. In Colonial times industry was largely agricultural in nature and fruit trees were in great demand. However, with the growth of non-agricultural industry and the development of large centers of population, the demand for fruit trees has declined and that for ornamentals has markedly increased. In fact, as previously stated, at least 80 per cent of all nursery stock at present consists of ornamental plants. In other words, most of the opportunities in the nursery business consist in the production and selling of ornamental plants.

What are the opportunities in the production of ornamental plants? To what extent are homes, private buildings and grounds, public buildings and grounds, highways, and industrial areas adequately landscaped? Although accurate information is unavailable, casual observation indicates that some homes are overlandscaped, that most homes are not landscaped whatever, and that, in general, many highways are laid down and factories and industrial areas established with no attention to adequate beautification. Thus, the beautification and ultimate value of many homes and private and public areas have not been fully realized.

Plant Patents. In 1930 the Congress of the United States passed a plant patent law. This law provides for the granting of patents to new and distinct varieties of asexually propagated crops only, provided the part used for propagation is not used for human consumption. Thus, new varieties of such crops as potato, Jerusalem artichoke, and sweetpotato are excluded.

The new and distinct varieties may be classified as follows: (1) Sports due to bud variation, (2) mutations due to self-pollination within a species, and (3) hybrids due to crossing between plants of two species, two varieties, or a species and a variety. The prime advantage of the law is the provision for specific monetary return to the originator for his efforts in developing new sorts. For example, the Joseph H. Hill Co., Richmond, Indiana, growers and breeders of greenhouse roses, developed and patented a new variety of rose called Better Times. Under the law the originator receives eight cents for each plant that he sells and the buyer agrees to maintain no more than the original number of plants that he bought. In other words, if a buyer bought 1000 plants of Better Times, he would

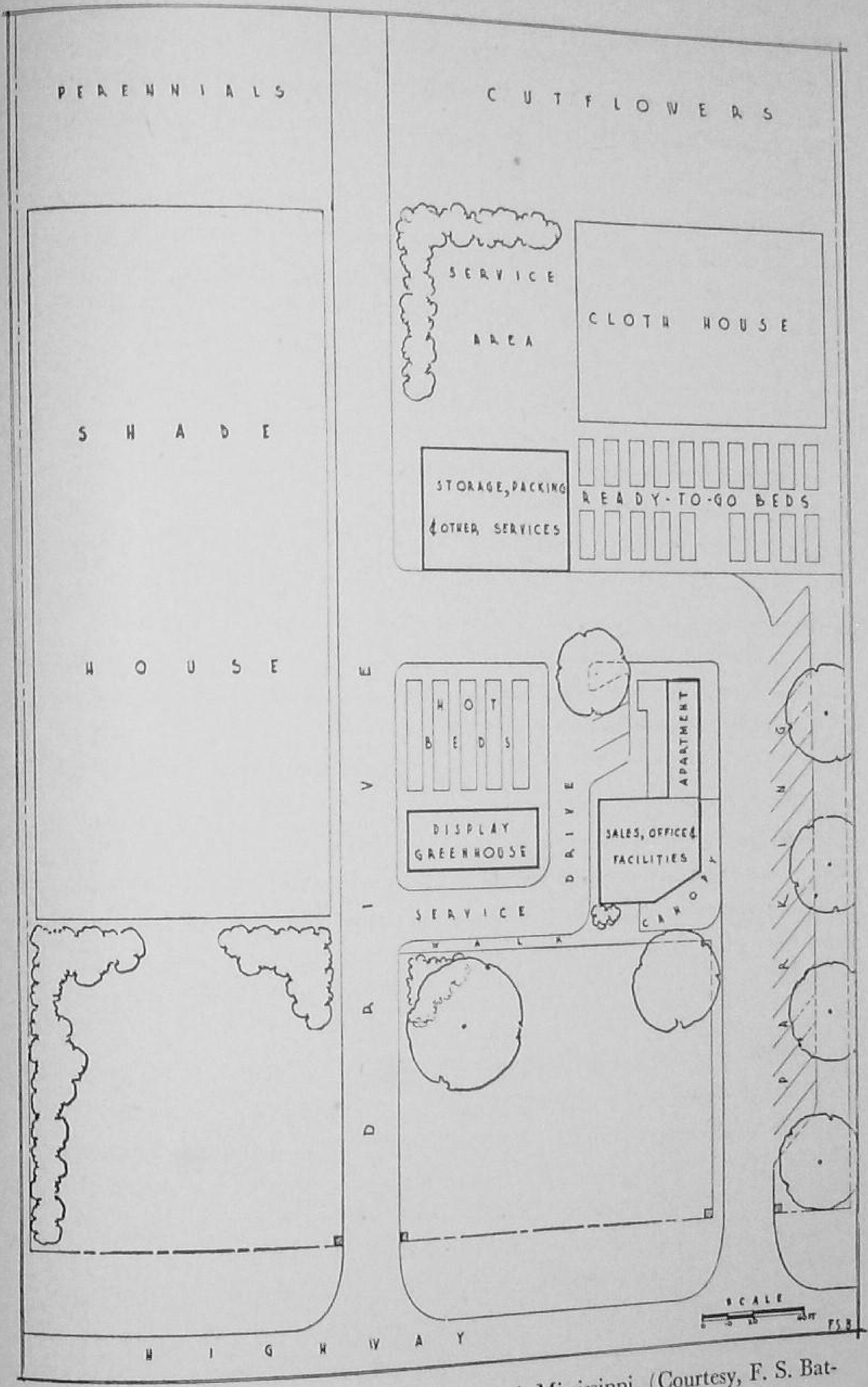


FIG. 145. Arrangement of a sales unit in south Mississippi. (Courtesy, F. S. Batson, Mississippi State College.)

agree to maintain no more than 1000 plants. In this way the originator has some control of the parent stock of new varieties. The plant patents are secured through and are administered by the Office of Commissioner of Patents, Washington, D. C.

Questions

1. What are nursery plants? What is the relative importance of the two groups?
2. Name the three phases of the nursery business.
3. State the objectives of the propagation unit, the production unit, and the sales unit.
4. The alley house of the greenhouse range should be wide enough to permit the use of a truck. Explain.
5. Water in which seed is soaked should be changed daily. Explain.
6. In your opinion, how does temperature of 32° to 40° F. combined with stratification shorten the rest period of seeds which have a rest period?
7. What does the nurseryman mean by the term well-ripened stock?
8. Applications of nitrogenous fertilizers, if made in late summer, prolong vegetative growth, delay maturity of the tissues, and make plants susceptible to winter injury. Explain.
9. A warm-rainy fall followed by a sudden killing frost usually results in marked injury to nursery stock. Explain.
10. A warm-sunny fall is most favorable for the conditioning of nursery plants for the winter. Explain.
11. In general, top-pruning should be avoided in late summer. Explain.
12. Deciduous trees for the lawn and for street planting are pruned to branch at different heights. Explain.
13. Show how root-pruning favors carbohydrate accumulation.
14. In general, nursery plants are removed in the fall, winter, or early spring. Explain.
15. What is meant by balling and burlapping?
16. Why is balling and burlapping necessary for evergreen stock?
17. Earth fills over the original soil of a tree is likely to kill the tree. Explain.
18. How can the bad effects of a fill be overcome?
19. The roots of wrapped nursery stock require air. Explain.
20. Many districts of the southern region are favorable for the production of nursery stock. Explain.
21. The sales area should provide an attractive landscaped atmosphere. Explain.
22. In general, which crops are excluded from the plant patent law?
23. How does a breeder benefit by securing a plant patent?

24

Horticulture and the Home

Assignment 32

It is not a home until it is planted.

Every home presents some kind of picture to all who approach or pass by, as well as to those living in the home. This picture may be pleasing, attractive, and inviting, or it may be bleak, barren, and ugly. A beautiful home with well-landscaped grounds not only increases the value of the property but also increases the usefulness of the property as well. It is a source of pride to the family, visitor, and passer-by. Landscaping the home grounds involves more than planting "bushes" around the base of the building. Landscaping is the improvement of the home grounds to combine appearance with usefulness for the family living on the property. It includes the maintenance of the property as well as the planning and planting of the property.

Beautifying the home is not necessarily an expensive proposition. Many attractive and useful native plants can be secured for little or no cost. A few dollars' worth of well-selected shrubs and trees in their proper place will make a world of difference in the looks of a home. Quite often, the home grounds can be more completely landscaped through the proper use of trees and lawn grasses than through an abundant use of shrubs.

To beautify the home effectively certain objectives should be attained. These are: (1) To secure attractive grounds, (2) to provide natural, easy approaches, (3) to obtain privacy for the family, (4) to provide for the

recreational needs of the family, and (5) to harmonize the home, buildings, yard, garden, and orchard into one complete unit.

THE LANDSCAPE PLAN

A plan for beautification is necessary not only to obtain these objectives and to effectively use plant materials, but also to relate the landscape developments to the needs of the family. It must be "custom-built" for the family. In other words, the plants that look well around one home may not suit a neighbor's home, or a flower garden may be a source of pride and recreation to an office worker but a burden to a farmer. Since the entire planting cannot be completed in one season, with the aid of a plan each year's work can be coördinated without loss of effort. It is easier to change the location of a tree or shrub on the plan than it is to remove the tree or shrub on the grounds. In general, the plan is made to scale and shows the location of each area, building, drive, fence, tree, and shrub. A key is used to show the name and number of trees and shrubs planted.

The home grounds consist of three areas: (1) Front or public,* (2) private, and (3) service. The *front* or *public area* includes the front lawn, entrance, front walk, drive, and base planting. It is developed primarily to serve as an attractive foreground and frame for the house and property. By no means should the front area be used to exhibit some exotic plant that the home likes, unless the plant fulfills a definite landscape need. The following guides are suggested for use in the development of the public area: (1) Make the lawn open and spacious in proper proportion, (2) confine shrubs to the borders, corners, and base of the buildings, (3) balance the plantings, both trees and shrubs, about an imaginary line through the entrance of the house or property, and (4) use only those trees and shrubs which will compliment the house to best advantage.

As stated previously, the lawn should be open and spacious. In general, for small properties the width preferably should be greater than the depth, and for large properties the depth may or may not exceed the width. In all cases a smooth surface, grass sodded lawn is very essential. Important factors in obtaining a satisfactory lawn are: (1) Thoroughly prepared, fertile soil, (2) use of well-adapted lawn plants, and (3) application of an adequate supply of nutrients and water. Lawns have many functions. They markedly reduce erosion; they reduce glare and cool the immediate surroundings; and they serve as an outdoor carpet. Lawn plants may be

*Although the use of the word "public" here may be misleading, it refers to the area exposed to the public view.

placed in two groups: (1) Warm-season and (2) cool-season. Some of the most common are presented in Table 28. What kind of lawn plants are used in your community?

Table 28

Warm-season and Cool-season Lawn Plants

Kind of Plant	*Leaf*		*Plant Height (inches)*	*‡Sod*	*Ability to Maintain Itself*	*How Propagated*
	**Width*	*†Color*				
Warm-season Plants						
Bermuda	n.	d.g.	2–3	d.	Low	sod, sprigs, seed
Fine-leaved Bermuda ...	n.	d.g.	2–3	d.	Low	sod, sprigs
St. Augustine .	m.b.	l.g.	3–4	m.d.	High	sod, sprigs
Centipede	b.	l.g.	3–4	d.	High	sod, sprigs
Carpet	b.	l.g.	2–3	d.	High	seed
Zoysia	n.	d.g.	3–4	d.	High	sod
Cool-season Plants						
Kentucky Blue.	n.	l.g.	3–4	m.d.	High	seed
Italian Rye ...	n.	g.	6–8	m.d.	High	seed

*n.=narrow; m.b.=moderately broad; b.=broad.
†l.g.=light green; g.=green; d.g.=dark green.
‡d.=dense; m.d.=moderately dense.

The entrance is located near the corner of the lawn in the direction of the most travel and at right angles to the main highway. The approach to the farmstead should be direct, though not necessarily straight to any of the buildings. However, it should be adapted to the ground form and at the same time be the most convenient and direct approach to the house and service area.

The base planting is the planting around the base of the house. Its function is to unite and harmonize the dwelling with the remainder of the grounds. The extensiveness of the planting depends on: (1) The size of the house and grounds, (2) the height of the house, and (3) the prominence of various features of the house. In general, with a large house and spacious grounds, large groups of plants are used. On the other hand, with a small house and small grounds, small groups of plants or even single specimens are used. Similarly, tall shrubs are used at the corners or angles and short plants at the steps or doorway. As a rule, shrubs are placed at least 3 feet from the building. Although some shrubs thrive best in shade

and others thrive best in the sun, most shrubs grow satisfactorily in sun or partial shade.

The *private area* consists mainly of recreational areas for the family and includes such features as the barbecue pit, family area, children's playground, flower garden, specimen shrubs or flowers, bird bath, lily pond, or rock garden. It is sometimes called the outdoor living room. The follow-

Table 29

LANDSCAPE USE OF SOME COMMON ORNAMENTAL PLANTS

Common Name	*Height in Feet*	*Adaptability to:*		†*Landscape Use*			
		Soil	**Light*	*Entrance*	*Corners and Angles*	*Wall Plantings*	*Border and Screen*
SHRUBS							
1 Bronze Elaeagnus	12–15	Dry	S-Sh		xx	x	xx
2 Chinese Firethorn	8–14	All	S		x	xx	xx
3 Common Box	5–16	Moist	Sh	xx		x	
4 English Ivy		All	S-Sh			xx	x
5 Glossy Abelia	5–8	All	S-Sh	xx	xx	xx	xx
6 India Privet	9–10	All	S-Sh	x	xx	x	xx
7 ‡Oakleaf Hydrangea	6–8	All	S-Sh		x	xx	xx
8 Pfitzer Juniper	8–15	All	S-Sh	xx	x	xx	x
9 Primrose Jasmine	5–9	All	S	x	x	xx	xx
10 Reeves Spirea	5–8	All	S	xx	xx	x	xx
11 Sargent Barberry	5–8	All	S-Sh	xx	xx	x	x
12 Spreading Euonymus	4–5	All	S-Sh	xx	x	xx	x
13 Winter Honeysuckle	6–8	Dry	S-Sh	x	xx	x	xx
14 ‡Yaupon	15–25	All	S-Sh	xx	x	xx	xx

Table 29—(Cont'd.)

Common Name	Height in Feet	Adaptability to:		†Landscape Use			
		Soil	*Light	Entrance	Corners and Angles	Wall Plantings	Border and Screen
TREES							
15 ‡American Redbud	20–35	All	S-Sh			x	xx
16 Common Crapemyrtle ...	15–25	All	S				xx
17 ‡Flowering Dogwood	15–35	All	S-Sh			x	xx
18 ‡Southern Magnolia	70–100	Moist	S-Sh				x
19 ‡Sugar Maple	70–90	All	S-Sh	(Along Gulf Coast use Florida Maple)			
20 ‡Water Oak	40–80	All	S-Sh				

*S=sun; Sh=shade; S-Sh=sun or shade.
†xx=first choice; x=second choice.
‡Native to southern region.

ing guides are suggested for use in the development of the private area: (1) Enclose the area to insure privacy and to form a background for landscape features, (2) arrange flower beds, rock garden, barbecue pit, or other feature around the perimeter, (3) allow the center to remain open, and (4) make the area easily accessible to the house and to other parts of the property.

The *service area* includes the outbuildings, laundry yard, vegetable garden, home orchard, or similar features. This area is sometimes screened from the front and from the dwelling. It should always be convenient to the kitchen and entrance drive.

Arrangement of Trees. In general, trees are planted in groups rather than in rows. With spacious grounds, the groups may consist of eight, ten, or twelve trees, and with non-spacious grounds they may consist of one, two, or three trees. Trees in the rear and on the sides of the lawn provide an effective frame and background and balance the landscape planting. For example, a group of trees at the southwest corner of the property with a corresponding group on the southeast corner frames and balances the planting. The planting of rapidly growing, short-lived trees such as cot-

tonwood, box elder, and soft maple with slowly growing, long-lived trees such as oak and elm to provide temporary shade in a relatively short time is advisable. Evergreen trees add color and are especially attractive in winter. Specimen trees are usually planted in the private area and in unusual places.

Arrangement of Shrubs. There are three general types of arrangement: (1) The angle or corner, (2) the entrance, and (3) the group.

The *angle* or *corner arrangement* is adapted to the inside or outside of corners and extends in two ways. The tall plants are planted in the back, the medium-sized next, and the short to the extreme outside. To give stability, angle and corner plantings should be triangular in outline. This arrangement is particularly useful in designating the limits of the yard or lawn, breaking the angles where the back and side lawns meet, and hiding objectional views.

The *entrance arrangement* may be single plants or groups of plants, formal or informal in character, depending on the type and arrangement of the entrance unit. This planting should be the most outstanding planting in the front area, since it is used to attract attention or to set off and scale the entrance unit. The formality of the planting is determined by whether the entrance unit appears formal or informal.

The *group arrangement* usually is used for mass effect. The tall plants are planted in the middle and the medium and short plants to the sides. This arrangement is particularly useful in separating the private and public lawn and planting along borders. Note the attractive planting of spirea in Figure 146.

Fig. 146. An attractive planting of spirea.

Hedges and Vines. Hedges and vines are used as screens, fences, or barriers and to provide seclusion in the private area. Vines are very valuable to screen unsightly buildings and to secure privacy.

In general, a satisfactory landscape planting has the following characteristics: (1) It fills a definite landscape need; (2) the plants are adapted to the soil and climate of the locality; and (3) the plants require a minimum of care. In particular, shrubs provide more unity when large groups of one or two kinds are used, and a more finished appearance when relatively wide spaces are used. Overplanting, a rather frequent occurrence, should be avoided. It results in shading of the leaves and in severe competition for water and nutrients. This results in a low rate of photosynthesis, poor growth, winter injury, and death. Thus, the use of large, healthy plants will avoid this undesirable condition. Table 29 presents a list of certain common trees and shrubs, together with their landscape uses.

Questions

1. The money used in landscaping the home is an excellent investment. Explain.
2. Landscaping the home grounds is more than planting "bushes" around the house. Explain.
3. What are the three areas of the home grounds? How should these areas be separated in actual plantings?
4. Contrast the features of the front lawn with those of the service area.
5. In general, straight lines should be avoided in informal plantings. Explain.
6. Groups of flowers, shrubs, and trees are undesirable in the center of the front lawn. Give reasons.
7. How does the lawn reduce glare and cool the immediate surroundings?
8. When sodium nitrate is broadcasted on lawns, it should be done when the grass is dry and preferably watered into the soil. Explain.
9. In general, the blade of the lawn mower should not be set lower than 1.5 to 2.0 inches. Explain.
10. If the lawn is cut regularly, the clippings should be allowed to remain. Explain.
11. Frequent and shallow watering of the lawn is likely to do more harm than good. Explain.
12. What are the lawn plants used in your locality?
13. Diagram the arrangement of tall, medium, and low shrubs to be used at a corner (1) inside angle, (2) outside angle.
14. How should shrubs be arranged in a group planting?
15. Where should specimen plants be used?
16. For what purpose are vines useful?

17. Name three locations where groups of shrubs may be placed to advantage.
18. Show how wide spacing of shrubs maintains a more desirable landscape appearance than close spacing.
19. Make a complete plan for beautifying the grounds of your home, using a few well-chosen trees and shrubs.

THE HOME VEGETABLE GARDEN

The value of vegetables in the diet has long been established. Vegetables are healthful. Certain sorts contain abundant minerals and vitamins and provide roughage; other sorts contain abundant carbohydrates and proteins. Since the health, development, and comfort of the family depends on an adequate diet, the best means of providing the necessary foods at the lowest possible cost should be considered.

The home vegetable garden can be made to provide an adequate supply of vegetables for the family during the growing season and for canning and storage for winter use. In many cases vegetables are not otherwise available because of the distance to markets or lack of purchasing power. Homegrown vegetables are higher in quality because they are consumed or preserved sooner after they are harvested. To a certain extent vegetables can be substituted for more costly food. Thus, the importance of the home vegetable garden is apparent.

If properly cared for and managed, a small plot of land is excellently productive. For example, garden authorities state that a properly managed half-acre garden will produce enough vegetables for the average farm family the year round. Because garden crops differ in their requirements and behavior, careful planning is essential. As previously stated, some mature in a relatively short time and make their best growth in the spring or fall. Others thrive best in the summer. Some require the entire growing season. Some are tall; others are relatively short.

The vegetable garden is an integral part of the landscape plan and should be planned and considered as such. Two rather distinct types of management are used: (1) As a distinct unit and (2) in combination with the flower and/or home orchard. Helpful rules in planning and operating the garden are: (1) Plant in rows—100 feet of any crop is usually sufficient; (2) place the perennials—asparagus, rhubarb, and small fruits—on one side of the garden to avoid interference with the tillage operations of the annual crops; (3) plant crops together which have similar methods of culture; (4) rotate the crops; (5) use the wheel hoe wherever

FIG. 147. A summer home garden in Oktibbeha County, Mississippi. (Courtesy, K. H. Buckley, Mississippi Agricultural Extension Service.)

possible; (6) supply water during times of drought; and (7) keep the garden free from weeds.

Succession Cropping. An important garden practice, succession cropping is simply a short rotation. It conserves space and labor. Examples follow: early maturing crops such as spinach, lettuce, endive, green onions, or mustard followed by beans, peas or tomatoes, pepper, and eggplant; cabbage, cauliflower, carrot, beets, peas, and kohlrabi followed by snap beans, cowpeas, or corn; beans followed by late cabbage, cauliflower, or sweet corn; sweet corn followed by beans, beets, lettuce, turnips, carrots, mustard, or spinach.

In general, the soil of the garden should be deep, friable, high in organic matter, well drained, and slightly acid. Liberal supplies of barnyard manure combined with deep plowing and thorough preparation of the seed bed are essential in successful home or farm gardening. Note the summer farm garden in Figure 147.

Questions

1. Enumerate the advantages of a home garden.
2. Make a simple plan for a home garden, showing the proper arrangement for the perennials, and long-season and short-season crops.

3. Outline the steps in properly preparing a garden previous to planting.
4. Make a list of vegetables which can be grown in your locality.
5. How many kinds can be grown and during how many months of the year can at least one vegetable be harvested?
6. What methods would you use to control the growth of vegetables?

THE HOME ORCHARD

As with the vegetable garden, the home orchard should be considered an integral part of the landscape plan. On relatively large properties, the trees are grown together as a unit and are grown primarily for their fruit. However, on small properties the trees may be grown for their landscape value as well as for their fruit. For example, peach trees are both useful and ornamental. They display flowers in the spring, produce fruit in the summer, and provide an attractive color in the fall, whereas flowering ornamentals such as the redbud, flowering peach, or dogwood display flowers and provide an attractive color only. Thus, fruit trees may be utilized for their landscape value as well as for their fruit.

Table 30

SUGGESTED FRUITS FOR A HOME ORCHARD

Fruit	*Trees or Plants*	*Number of Varieties Recommended*	*Planting Distance (feet)*	*Relative Freedom from Pests*
pecan	4	3	60×60	Free
apple	8	7	36×36	Not free
peach	12	7	20×20	Not free
plum	6	3	20×20	Not free
cherry	3	3	20×20	Not free
Muscadine grape .	4	2	10×30	Free
other grapes	8	3	10×10	Not free
brambles	40	2	5×5	Free
strawberry	400	2	3×1	Free
fig	4	2	15×15	Free

Important factors in the selection of appropriate kinds and varieties of fruits are: (1) Resistance or susceptibility to pests and (2) adaptation to the local environment. As is well known, certain fruits are susceptible to many insects and diseases and others are relatively free. In general, fruits which are susceptible require the application of dusts and/or sprays which must be applied at the right time and in the proper dosage. This practice is relatively expensive and time consuming and frequently requires special

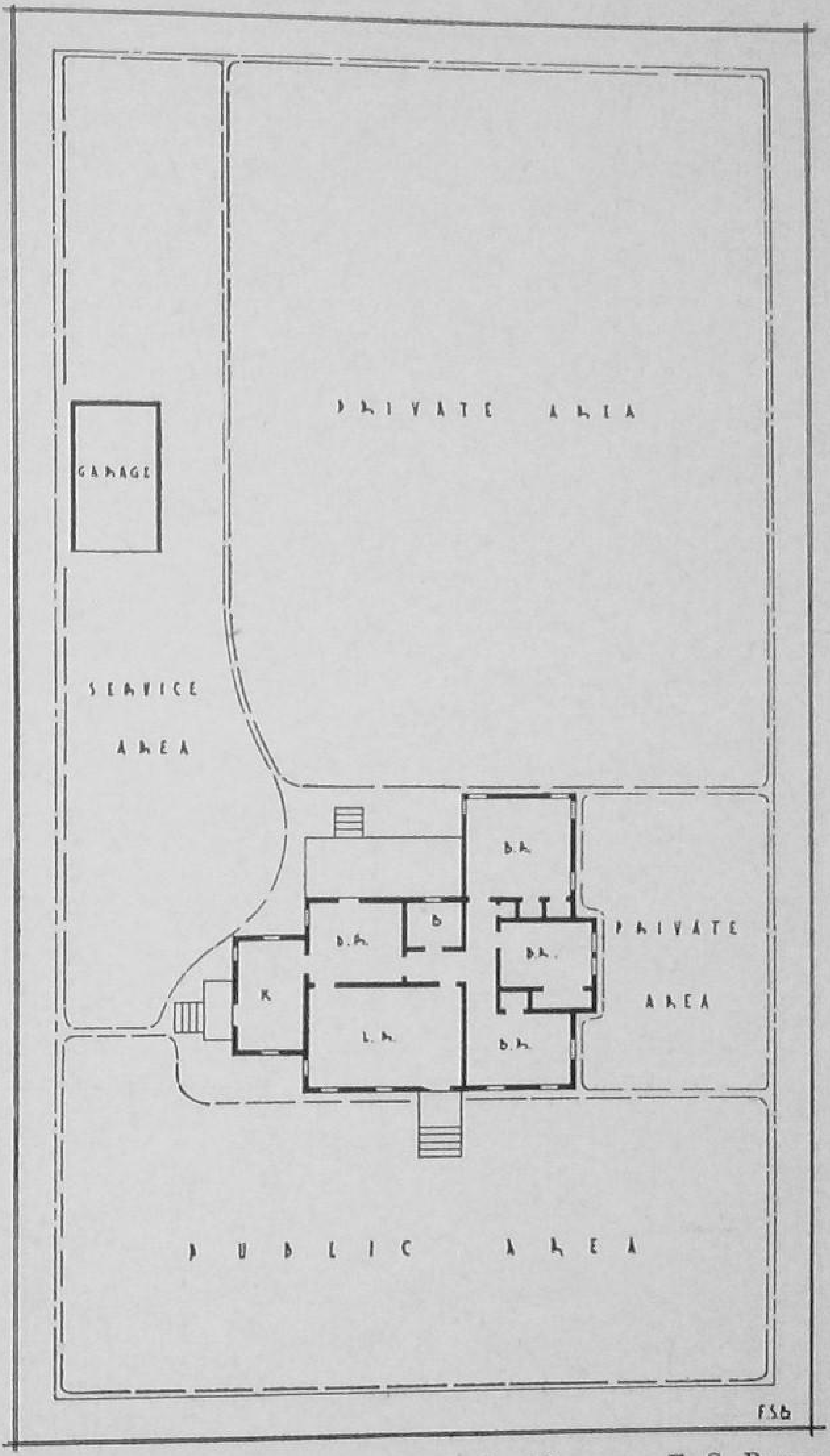


FIG. 148. Principal areas of the home grounds. (Courtesy, F. S. Batson, Mississippi State College.)

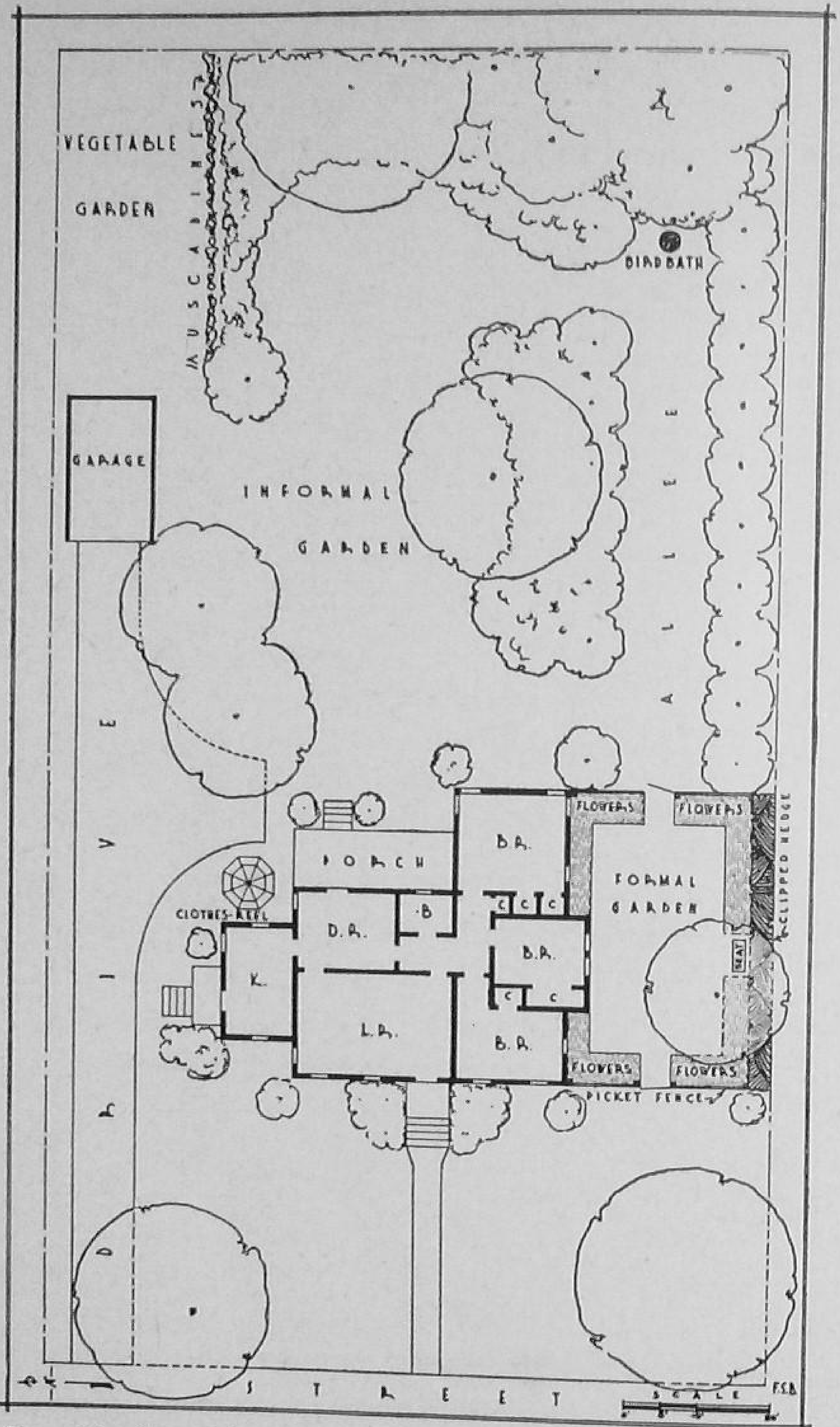


FIG. 149. Beautification of home grounds of Figure 148. (Courtesy, F. S. Batson, Mississippi State College.)

equipment. Thus, where facilities, time, or interest is limited, greater satisfaction is likely to be obtained with fruits which are relatively free from pests. Note the relative freedom from pests of the crops listed in Table 30.

An important factor of the environment is temperature. As discussed in Chapter 4, horticultural crops may be divided into two groups: (1) The cool-season and (2) the warm-season. Thus, for the reasons given in Chapter 4 and with other factors favorable, cool-season fruits thrive best in the northern half or in the elevated sections of the southern half of the United States, and warm-season fruits thrive best in the southern half of the country. In other words, all of the fruits listed in Table 30 will seldom be grown in any one home orchard. For example, in California the English walnut takes the place of the pecan. In the northern states, the apple, peach, cherry, and black grape take the place of the pecan, Muscadine grape, and fig, and along the Gulf Coast and in many parts of Florida, citrus fruits take the place of the apple and peach. Study the landscape plan and development of the home grounds in Figures 148 and 149.

Questions

1. Contrast the peach and the redbud for use in landscaping small properties.
2. Show how fruit trees can be used to screen out undesirable views and to provide a background for the house.
3. In general, the average homemaker is more successful with bramble fruits, figs, and strawberries than with peaches, apples, and pears. Explain.

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